# JOURNAL

OF THE

# FRANKLIN INSTITUTE

## OF THE STATE OF PENNSYLVANIA,

FOR THE

## PROMOTION OF THE MECHANIC ARTS.

VOL. CIII. FEBRUARY, 1877. No. 2.


## EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

---

**The Scope of Governmental Interference for the Prevention of Accidents.**—Two catastrophies of exceedingly deplorable character have recently occurred, which bring forcibly before the public the necessity of some preventive measures. The burning of a theatre in Brooklyn, on the night of the 5th of December last, has cost over 300 lives; and the falling of a bridge at Ashtabula, Ohio, on the line of the Lake Shore Railroad, on the night of the 29th of the same month, has involved the lives of over 160 persons in the disaster. The question of what is to be done to prevent similar catastrophies, is now a proper one for consideration.

It can be asserted without exaggeration, and upon grounds which will bear examination and be supported by abundant proof, that there are many theatres in any of our cities, and many bridges on some of our railroads, as liable to an accident, possibly more liable, than those by which so deplorable results have ensued. The theatre in Brooklyn was not an exceptionally dangerous structure—a skilled

architect in this class of building was entrusted with its erection—and no reckless or unusual disregard of precautions existed, no assumption of risk was made to save cost in construction. Subsequent examination of the theatres of Philadelphia disclosed that much less adequate means for escape of an audience have been provided in several theatres which have been constructed and used for years. The chances that a fire should occur at all in any theatre, *any year*, is not, perhaps, 1 in 200 or 300, whence the chance *any day* is but 1 in 75,000 or 110,000; while the chance that a fire will occur when a performance is going on, is not over one-half these ratios, and 1 to 150,000 to 200,000 is, perhaps, a fair estimate of the risk of burning during the time of a performance on any given day. Even this great ratio is increased when the individual chance of escaping from the fire is taken into the account, so that the risk of life to any man, woman or child, in any theatre, any night, is not 1 in 1,000,000. The risk of loss of property by owners each year is, as has been taken, 1 in 200 or 1 in 300, and the insurance is cheerfully paid, after which no feeling of risk remains with the owner. Even if the construction is admitted to be dangerous, the ratio of extra danger is met by an owner in enhanced premiums, at much less expense than the cost of alteration to remove danger, while the underwriter is happy in the increased profit which the rate of premium affords. These small risks are accepted by the entire community. When, in the fulness of time, the disaster at Brooklyn, or elsewhere, occurs, the immediate shock will affect the pleasure-seeker, and attendance will fall away from places of amusement, a spasmodic official inquiry will be instituted, a number of moral communications be offered to the newspapers, and a few which are entirely impersonal, as regards any possible advertising patrons, will be published; but the seven days' wonder will pass away, and the old rule of "taking the chances," will be re-established with greater strength, as the next catastrophe *may* not not be so dreadful as the last.

The same considerations attach to the railway accident. Statistics exhibit that it is almost safer to live in a railway carriage than in one's house. Many thousand trains, running many thousand miles, and transporting many thousand passengers, will have passed over railways without one accident involving loss of life to a passenger, and each passenger takes the risk for himself with little fear or

scruple. Cheap construction, cheap management, large dividends, are substantial evidences of skill, ability, and enterprise in the direction of a railroad. The directing manager takes the risk. Not every unsafe bridge falls; not every bridge that falls involves *considerable* loss of life or property. Powder magazines do not frequently blow up, and the keepers of such magazines sleep as soundly at their appointed hours of rest as other people. This proposition that not every unsafe bridge falls, is readily admitted by all practical engineers. There are unquestionably hundreds of bridges on lines of running railroads as unsafe in theory as that at Ashtabula was from its beginning. Constructions vary in diverse ways in almost infinite combinations, and strains or stresses are brought into action by these variations in very unexpected ways. Imperfections of material are a necessary accompaniment to material itself, and tests which might be instituted to find out flaws or defects not unfrequently impair the strength of the tested piece to, or beyond, the limit of safety. Both theoretical knowledge and sound judgment, therefore, are demanded for bridge construction or inspection, but neither knowledge nor judgment can assert that an unsafe bridge will certainly fail, if such a bridge has only a degree of unsafety. For the benefit of non-professional readers it may be permitted to enlarge on this point, by saying that average wrought iron will sustain a pulling strain of 50,000 to 60,000 pounds to each square inch of section under strain, but it will begin to yield—extend permanently—at about 18,000 to 20,000 pounds per square inch. When this extension commences the iron becomes weaker for bearing a shock or blow, and repeated extensions finally break the piece. It follows that the limit of absolute strength for railroad bridge use is 18,000 to 20,000 pounds per square inch. The same figures nearly, apply to compressive strength of wrought iron, only the effect of want of homogeneity of iron in any pillar is far more disastrous than such effect in a rod under tension, as the yielding of the softer parts may—in fact do—tend to *cripple* a pillar and bring into action some severe cross-strains on the unyielding portions. Whence the strength of a strut or pillar depends on the ratio of its sectional dimensions to its length by known laws, founded on experiments on pillars of different proportions. Finally, taking all the effects of maximum loads on a railroad bridge, it is good practice to provide such sections of wrought iron as will give about 10,000 pounds tensional strain on long ties, and 8000

pounds of compressive strain on columns of 20 diameters in length. At the same time the load on a bridge, of long span, is taken at a maximum of 2000 to 3000 pounds per running foot of track. It will be seen that these figures are from one-fifth to one-sixth what iron *might* bear, and that any bridge may stand for years, although weaker than good practice has dictated.

It has been the purpose of these remarks to show that there exists no inducement on the part of the owners of theatres and the managers of railroads to *prevent* the recurrence of these accidents in any other way than what they have already done. As individuals, they may feel "very bad about it," when a disaster occurs; they may even go so far as the unfortunate Mr. Collins, the engineer of the Lake Shore Road, who has found his responsibility unbearable; while the evidence so far given makes it certain that a condemnation of the bridge on his part would have merely dismissed him from his post as it did a previous engineer. But all this affords no protection to the public, and Governmental interference becomes, therefore, the only way to secure the desired end.

With regard to the buildings, it is probable that local or preferably State legislation should be taken, and a rigid inspection, with power to enforce results, established. As to the railroads, there is a special constitutional provision, which gives Congress power over them, and it should now be exerted to the utmost. The happy results which have come from the inspection of steamboats, where precisely the same influence had *perpetuated* a long series of disasters, indicate what can be anticipated from a Board of Inspection of Railways of the United States with similar authority.

The passage of law obliging owners or directors to have inspections made previous to occupancy or use, and at stated intervals afterwards, by their own officers or employees, however competent as architects or engineers they might be, would fail to meet the exigencies, as recent accidents show such inspections would have a controlling bias in favor of the employers' interest as a matter of economy or profit. It is between the public as guests or travelers, and the owners and directors as hosts or common carriers, that the question lies. The *judges* should be not only competent, but amenable to none but the public authorities. The enforcement of proper laws might work some hardship at first, in trouble and immediate outlay, but in the end it would prove profitable to theatres and railroads.

# Franklin Institute.

HALL OF THE INSTITUTE, Jan. 17th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were 150 members and 10 visitors present.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 40 persons were elected members of the Institute, and the following donations were made to the library:

Report of the permanent committee of the first international congress at Vienna, meeting at London, 1876. From the meteorological committee.

Discussions on technical education by the American societies of civil and mining engineering. Easton, Pa., 1876. From the Am. Soc. Mining Eng's.

Verhandlungen des naturhshistorisch-medecinischen Vereins zu Heidelberg. New ser. Vol. I, Pt. 4. From the union.

Catalogue of the collective exposition at the Centennial exhibition in 1876, at Philad'a, of the Netherlands booksellers' association. Amsterdam, 1876. From Dr. Geo. J. Ziegler, Philad'a.

Report of the board of health of the city and port of Philad'a to the Mayor, for the year 1875. From Geo. E. Chambers, registrar of the board.

Memoires of the imperial Russian technical society and collection of patents issued in the department of commerce and manufacture. 1876. 4 vols. From the society.

Secular change of magnetic declination in the United States and other parts of North America, 1874. From the U. S. coast survey.

Report on the North Sea canal of Holland, and on the improvement of navigation from Rotterdam to the sea.

(To be continued in next number.)

The President presented the following Annual Report of the Board of Managers, which was adopted;

## REPORT OF THE BOARD OF MANAGERS TO THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, FOR THE PROMOTION OF THE MECHANIC ARTS, FOR THE YEAR 1876.

Your Board of Managers beg respectfully to submit the following Report:

*Members.*—During the year 1876 there were elected one hundred and thirty-two members—and thirty-one resignations.

*Treasurer's Report.*—The report of the Treasurer herewith submitted as extracted from the minutes of the Board, presents the following exhibit:

| | |
|---|---|
| Balance on hand Jan. 1st, 1876, . . . | $2,218.65 |
| Receipts during the year from all sources, . | 17,622.71 |
| Total, . . . . . | $19,841.36 |
| Expenditures and investments during the year, | 18,849.35 |
| Leaving a balance on hand, Dec. 31, 1876, of | $992.01 |

*Premiums and Medals.*—During the past year the following medals and premiums were awarded:

Elliott Cresson gold medal to W. G. A. Bonwill, for his electro-magnetic mallet for dental purposes.

Scott Legacy premium and medal to C. Tyson, for his machine for uniting the soles to boots and shoes; to Morris L. Orum, for his flexible mandril for bending metal pipes, and to Chambers, Bros. & Co. for their brick-making machine.

*The Journal of the Institute.*—The Journal, which is under the management of the editor and the committee on publication, has not been self-sustaining for the past year.

*Drawing School.*—The Board are able to report the night drawing school as having been reasonably satisfactory in its operations; although they have to state that in consequence of the general depression in business, its numbers during the year have been somewhat diminished. The attendance at the school in the Spring was 103, and in the Fall was 81.

*Lectures.*—The lectures given during the earlier part of the year, from Jan. 4th, to March 21st, were: by C. B. Dudley, on Artificial Ice; by Robert Briggs, on Steam Boilers; by Prof. E. D. Cope, on Paleontology; by Joseph Zentmayer, on Lenses; by Prof. P. E. Chase, on Physics; by Prof. Persifor Frazer, Jr., on Geology; by M. B. Snyder, on Astronomical Spectroscopy; by Prof. L. M. Haupt, on Tunneling.

The attendance on these lectures was generally good and on some of them the lecture room was crowded.

The lectures arranged for this Winter were of two classes, the one being of the usual popular scientific character, admitting of extensive

experimental illustration, and the other for elementary instruction. The subjects chosen for the latter series were the first principles of dynamics, and elementary chemistry.

Such series of elementary lectures were in former years given each season, and the privilege of attendance on them was considered one of the most valuable rights of membership, and they were undertaken the present season with the hope of renewing the interest formerly felt for them, and of extending this kind of instruction to the younger members, and to those who may hereafter become such.

The lectures given from Nov. 14th to the end of the year were six on Light, brilliantly illustrated, by Prof. E. J. Houston, and five on the first principles of Dynamics, by Prof. W. D. Marks. The attendance on these lectures has been larger than usual, and especially those on Light, when the Hall has been nightly crowded.

Prof. Houston also gave, gratuitously, in Christmas week, one lecture on "Familiar Science" to the children and wards of members, which was highly appreciated.

*Phonography.*—Courses of instruction in Phonography have been given in the Hall of the Institute since November last, by Mr. D. S. Holman, Actuary. These courses, introduced for the first time systematically in the Institute, have proved very popular and attractive, and promise to become a valuable addition to the useful work of the Institute. So great has been the interest awakened in this variety of shorthand, by the efforts of Mr. Holman, that the number already registered in his classes reaches 131, and is steadily increasing.

*Monthly Meetings of the Institute.*—The attendance at the monthly meetings of members and strangers has been well maintained during the year, and interesting communications and noteworthy inventions and novelties have been presented and discussed on those occasions.

*Library.*—A statement of the condition of the library will be presented by the Committee on the Library.

The reports of the Committees on Models and on Science and the Arts will be read at this meeting, and will show what has been done in that connection.

*Centennial Exhibition.*—Believing that the objects of the Institute would be advanced by extending hospitalities to strangers visiting the Exhibition, the Board of Managers quite early secured a room in Machinery Hall for an office and reception room, where strangers

would be welcomed and could confer with some officers of the Institute on matters of mutual interest.

A Committee of Reception was appointed to take charge of the room and receive and give information to visitors. The report of this committee, submitted to the Institute at the last meeting, shows its operations.[i] To make the reception room the more useful to visitors, the Board directed the Secretary to ask publishers of desirable journals to donate for that use the numbers of their publications from May 1st to November 1st, which was very generously responded to by leading scientific and technical journals of this country and Europe.

The Institute also extended the free use of its library and reading room to all members of kindred societies at home and abroad, and this privilege was largely availed of by both private and official visitors.

*Exhibitions.*—It appearing to the Board that the holding of annual exhibitions by the Institute was not advisable, and that one in every three or four years would be often enough, and anticipating the great benefit to be derived from such an arrangement, the Committee on Exhibitions was authorized to correspond with other societies of like character in the Atlantic cities with the view to quadrennial exhibitions in Boston, New York, Philadelphia and Baltimore. This resulted in a convention[ii] of the representatives of the Mass. Charitable Mechanics' Ass'n, of Boston; the Franklin Institute, and the Maryland Institute of Baltimore, and finally in the adoption by these societies of an agreement to hold exhibitions triennially (or quadrennially if the American Institute of New York will join in the arrangement) in their respective cities.

As one of the great difficulties hitherto encountered by the Institute in holding its exhibitions has been the procuring of a suitable building, and as the Machinery Hall of the Centennial Exhibition was built and is owned by this city, the Board of Managers petitioned Councils[iii] to maintain and preserve that building for this and other public purposes, which resulted in the adoption of the following ordinance, approved by the Mayor Dec. 12th, 1876:

---

[i] The proceedings of this convention will be found published in Vol. cii, page 291, JOURNAL OF THE FRANKLIN INSTITUTE.

[ii] See Vol. cii, page 293, of the JOURNAL.

[iii] See Vol. ciii, page 8, of the JOURNAL.

"An ordinance for the retention, use, and management of Machinery Hall, in Fairmount Park.

"WHEREAS, The building recently used by the International Exposition, in Fairmount Park, and known as Machinery Hall, was built by and paid for with the money of the City of Philadelphia; and whereas, members of the Franklin Institute and other citizens have requested Councils that the building may remain, to be made available for useful purposes; and whereas, the Park Commission are willing that the said building may continue in its present location so long as the city desires it; therefore,

"Section 1. The Select and Common Councils of the City of Philadelphia do ordain:

"That Machinery Hall, within Fairmount Park, shall be permitted to remain until otherwise ordered by Councils, and that the same be placed in charge of the Park Commission, for the purposes of public exhibitions by the Franklin Institute, and such other purposes and objects, and under such regulations as the said Commissioners may deem expedient; the Councils hereby reserving to the city the exclusive ownership of the building, and the right to reclaim and remove it whenever they choose so to do."

With a view to aid in the illustration of certain lectures, and to enable exhibitors to show at the monthly meetings the operation of their machines or models, the curators have been authorized, and have purchased a steam engine of six-horse power.

In conclusion, the Board of Managers feel that they can again cordially congratulate the Institute upon its increased prosperity, and its promising prospects in the future.

All of which is respectfully submitted.

By order of the Board. R. E. ROGERS, *President.*

---

The Committees on Library, Models, and Science and the Arts, presented their reports as follows, which were adopted:

The Committee on Library would respectfully report that they have held monthly meetings with the usual good attendance. The catalogue of the books, which was in progress at the beginning of the year, was completed and printed in August, and makes an 8vo volume of 452 pages, and is a full and complete reference to all the books in the Library. The cost of this work was quite large, but in view of the increased usefulness of the Library, your Committee consider the outlay fully warranted.

The Catalogue, bound in cloth, is now for sale by the Actuary, at $2.00 per copy.

The following additions have been made to the Library:

| | |
|---|---|
| Bound volumes donated, including 420 vols. formerly deposited by A. Seybert, | 599 |
| Bound volumes purchased, | 150 |
| Number of volumes, Exchanges, bound, | 266 |
| " " British Patents, bound, | 286 |
| " " other books, bound, | 147 |
| Total number of bound vols. added to the Library, | 1448 |
| Number of Pamphlets donated to the Library, | 408 |
| There are now in the Library bound vols. of British Patents, | 2717 |
| Indices to same, | 66 |
| Abridgments, | 52 |
| American Patents, | 177 |
| Total number of bound vols. in Library, | 11,966 |

There is also a large number of unbound vols., but the number not ascertained.

Our set of British Patent Office publications, consisting of Patent specifications, abridgments and indices, is now full, with now and then a rare exception, and we are receiving the current numbers quite regularly, as also the Commissioner of Patents Journal, weekly.

The set of American Patents is complete from 1841 to date, so far as published.

| | |
|---|---|
| There have been expended during the year, for the purchase of new books, | $1260 84 |
| There have been expended during the year, for binding books, | 453 70 |
| Making a total, for the improvement of Library, of | $1714 54 |
| And there still remains a balance from the appropriation of $5000 for the improvement of the Library, made Jan. 13th, 1875, of | 1403 54 |
| There were expended from the subscription fund, for binding British Patents, | 115 25 |
| And there still remains a balance of | 71 15 |

As was anticipated at the beginning of the year, the attendance at the Library, and its use by members, is much greater than before, and is still increasing.

By order of the Committee. CHAS. BULLOCK, *Chairman.*

---

The Committee on Models respectfully report that very little has been done to the models during the year, for want of space in which to properly display them.

The Board of Managers at its meeting in December passed a resolution requesting the committee to report to the Board the extent and condition of the collection of models belonging to the Institute.

As there was no list of the models it was decided to take the measure of the larger and more important models and relics distributed about the room and to measure the shelves now occupied by the smaller ones.

One hundred and eighty models were measured and numbered, and entered in a book, and it is proposed to continue this at some future time to cover the whole collection.

The actual shelf room necessary to hold the models, when placed in contact with each other, is thus estimated at about 1000 sq. feet.

As models should have not less than twice their dimensions on the shelf, to display them properly, our collection will require 2000 sq. feet of shelf room.

Of all the models in the collection about one-third requires more or less repairs, and all need a thorough cleaning. There are a number of models of considerable historic interest in connection with the Institute, and a large number representing inventions passed upon by the Committee on Science and the Arts, and its predecessor, the Committee on Inventions; and a smaller portion are models remaining from early exhibitions; in fact the collection as a whole derives its greatest interest because of its connection with the work of the Institute. There are, however, many exceptions in which the models are in themselves of value, as representing progress in the arts, and for educational purposes.

While recognizing the advantages to be derived from the collection, if properly displayed, the committee, in view of the financial condition of the Institute, have not felt warranted in recommending the large appropriation necessary to accomplish it.

By order of the Committee.

C. CHABOT, *Chairman.*

---

The Committee on Science and the Arts would respectfully report that there has been an unusual amount of interest manifested by the members during the year, as well as a larger number of applications for reports on inventions.

The average attendance during the year at twelve stated and one adjourned meetings, was $30\frac{8}{13}$ persons, the highest number being 40 in May, and the lowest, 21 in July.

| | |
|---|---|
| At the beginning of the year, there were pending applications for reports, . . . . . | 18 |
| Number of applications during the year, . . | 61 |
| | 79 |
| Number of reports adopted during the year, . . | 29 |
| " " applications withdrawn, . . . | 3 |
| " " " dismissed. . . . . | 9 |
| " " " pending Dec. 31st, . . | 38 |
| | 79 |

The medals recommended, and which were afterward awarded by the Board of Managers, were two, as follows:

The Scott Legacy premium and medal to Morris L. Orum, for his flexible mandril for bending metal pipes, and the Scott Legacy premium and medal to Chambers, Bros. & Co., for their brick-making machine.

The amount of money expended, during the year, for notices, is $46.40.

By order of the Committee.

COLEMAN SELLERS, *Chairman.*

---

On motion the order of business was suspended and Mr. Wm. Welsh offered the following, which was seconded by Mr. J. W. Nystrom, and unanimously adopted:

WHEREAS, It is alleged and generally believed that the education of children in our public schools and in private seminaries, does not dignify labor or furnish the pupils with any special preparation for mechanical and other useful arts, and

WHEREAS, The Franklin Institute of the State of Pennsylvania was founded to promote and encourage manufactures and mechanical and useful arts by all such measures as its members may judge expedient; therefore,

*Resolved*, That a Committee of seven members of this Institute be appointed, with power to confer with Boards of Education, Directors and Teachers of Schools, and with others interested in the special training of youth of both sexes, for industrial pursuits; reporting to this Institute the result of their conferences, and the extent of the alleged defect in education, with such remedial measures as the Committee may deem practicable.

Mr. Welsh moved that the President be a member of the Committee, and that he appoint the remainder at his leisure, which was carried.

The Committee, as appointed by the President, is constituted as follows:

Wm. Welsh, *Chairman*, Dr. R. E. Rogers, Jas. S. Whitney, Wm. A. Ingham, Jos. M. Wilson, Enoch Lewis, F. O. Horstmann, and J. B. Knight, *Secretary*.

The President called Vice-President J. E. Mitchell to the chair.

The Tellers presented their Report of the Annual Election held this day, which was accepted, and in accordance therewith the chair declared the following members elected:

*President*, Robert E. Rogers, M. D.
*Vice-President*, Henry G. Morris.
*Secretary*, J. B. Knight.
*Treasurer*, Fred. Fraley.
*Managers to serve three years*, Prof. E. J. Houston, Enoch Lewis, C. H. Banes, Wm. Helme, Sam'l Sartain, Chas. Bullock, John Sartain, C. Chabot.
*Auditor*, Wm. Biddle.
*Representative to the Penna. Museum and School of Industrial Art*, J. B. Knight.

The Secretary presented his Report, which embraced a number of attachments for improving the draft of chimneys, and the heating and ventilation of buildings, designed by Mr. Wm. Welsh[i]; J. A. Lock's Paper Pulley-cover; Marsland's Water Meter; Specimens of tissue paper and cotton cloth, rendered incombustible by being saturated in Tungstate of Soda; and a cylindrical Holtz Electric Machine, made of Paraffined paper, designed and built by Prof. Elihu Thomson.[ii]

Mr. J. B. Knight, representative of the Institute in the Board of Trustees of the Penn'a Museum and School of Industrial Art, presented the following report:

PENNSYLVANIA MUSEUM AND SCHOOL OF INDUSTRIAL ART.—At the meeting of the Institute in June last, I made a Report[iii] covering the principal features in the progress of the association up to that time, and would now present the following:

It having been the original intention in organizing the museum, to take advantage of the opportunities offered by the International Exhibition, and the subscriptions having reached an amount which

[i] [ii] Descriptions of the Ventilating apparatus of Mr. Welsh, and of the Holtz Machine of Prof. Thomson, are necessarily deferred to the next number of the JOURNAL.

[iii] See JOURNAL for August, 1876, page 79.

warranted the expenditure, the Board appointed a Committee on Selection, and clothed it with authority to purchase at the exhibition, suitable objects for the museum collection to the value of $25,000. With this, and under special appropriations, they have made very judicious purchases to more than $33,000. The promises of assistance and donations from foreign commissions, referred to in my former report, have been fully realized, and by them many valuable additions have been donated to the collection.

The Board of Trustees, in its Annual Report, acknowledge the great interest in the museum manifested by persons outside of Philadelphia, and especially to that of Mr. P. Cunliffe Owen, of the South Kensington Museum, London, who, among other important acts, has secured permission from his government to have reproduced for our Museum, a number of pieces of royal plate of great historical and artistic value, now in the Tower of London.

The Board was also fortunate in having secured Dr. Christopher Dresser to deliver under its auspices, three lectures on Industrial Art Education, which were of great value, both from their intrinsic merit and the marked influence they had in directing attention to the importance of the work undertaken by the Museum.

The Governor of the Commonwealth, in his recent message to the Legislature, again pointed to the necessity of Industrial Art Education, and refers to the important part to be borne by the Museum, and asks the Legislature to "seriously consider whether * * * * the "State ought not to extend a hand to place upon a firm foundation "a work of so much public utility."

The time of occupying Memorial Hall is necessarily somewhat delayed, in order to make the required preparations for receiving and arranging the objects; but it is expected that the Museum will be opened to the public during the coming Spring.

Meanwhile, with a view of bringing the Museum more prominently before the public, the Board of Trustees authorized the holding of a temporary exhibition, consisting of such objects from its own collection as are available, supplemented by objects loaned from private collections. Arrangements were made with the Academy of Fine Arts for the use of the south tier of galleries in its building, and the exhibition was opened on Jan. 16th, and will continue open until March 31st.

It will be remembered that one of the principle means to be employed by the organization in its work of improving the character of

our manufactures, is the establishment of Schools of Art, as applied to the industries, where drawing and designing, in their more advanced stage, shall be thoroughly taught. A widespread interest is manifested by our citizens, and there has been much inquiry regarding the opening of the schools, and which, with other evidence of a strong demand for such instruction as shall be available in making a livelihood, shows that the time is ripe for the establishment of the Museum's schools. The Board of Trustees has been unable as yet to complete the details necessary to put them in operation, but timely notice will be given of the opening.

The members of the museum, realizing the great public importance of giving a more practical direction to the instruction in our public schools, and how much the work of establishing art schools will be advanced thereby, adopted a Report from its Committee on Education on that subject at the Annual Meeting of the Corporation, held Jan. 8th, 1877, in which reference is made to "the position of Phil-"adelphia as a manufacturing city, and to the fact that the large "majority of the children being educated at the public expense, are "the sons and daughters of those engaged in the multifarious indus-"tries of the city, and who in their turn will become mechanics and "artisans. * * * * Heretofore, it is well known that the "instruction in our schools, most excellent of its kind, has been almost "exclusively of a literary character, and * * * * would, no "doubt, be of the greatest value to a resident of a city devoted to "letters or to mercantile pursuits, but in such a city as our own, "where the whirl of the loom, the stroke of the hammer, and the "countless sounds of a people actively engaged in industries of the "most practical character, daily strike upon the ear, your Committee "are of the opinion that the present plan of instructing the young "of Philadelphia is by no means complete, and that here especially "the study of drawing should be enforced as an essential branch of "education.

"The establishment of a complete system of Industrial Art Edu-"cation by this Corporation, will supply opportunities for the instruc-"tion and training of teachers, which will obviate the necessity of the "very large expenditure involved in the formation and support of a "normal Art School."

Owing to the very depressed condition of business, the difficulties in obtaining subscriptions to any enterprise of this nature, have been very great, but under the circumstances the success of the museum in

this regard, is considered quite encouraging, the amount secured up to Dec. 31st, 1876, being $70,000, and the number of persons elected members is one hundred and fifty.

It is important, however, to keep in mind the fact that the Museum is supported entirely by subscription, and I would urge upon the members of the Institute the importance of increasing the membership and the subscriptions to its fund, thus enabling it to assist in carrying out the principle upon which the Franklin Institute is founded—the promotion of the mechanic arts.

Members and subscribers have the following privileges:

Life Members paying one hundred dollars, and Subscribers to the amount of two hundred dollars, are entitled to one season ticket annually, or in lieu thereof, to twenty-four single tickets of admission to the Museum and its collections for each one hundred dollars subscribed.

Annual Members paying ten dollars yearly, are entitled to one season ticket and sixteen single admission tickets, or in lieu thereof, to forty single admission tickets.

As showing the intimate connection between the Museum and the Institute, I would call your attention to the fact that out of thirty-two Trustees composing the Board, thirteen are Members of the Institute, and five of these are Members of the Board of Managers of the Institute, and one of these, Mr. Coleman Sellers, is President of the Museum.

J. B. KNIGHT,
*Trustee in behalf of the Franklin Inst.*

Mr. F. M. M. Beall offered the following:

WHEREAS, A bill is at present pending before Congress, asking aid for carrying into execution the scheme of Capt. H. W. Howgate, of the Signal Service, for reaching and exploring the region about the north pole on the plan of colonization,

*Resolved*, That the Franklin Institute approve of this plan, not only for its economy, but for its apparent practicability, and believe it to be the most feasible plan yet offered.

On motion of Mr. Close the consideration of the subject was postponed to the next meeting.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

# Civil and Mechanical Engineering.

## THE ESCAPEMENT OF THE "HIPP" CHRONOGRAPH, AND THE MEASUREMENT OF SMALL INTERVALS OF TIME BY ITS MEANS.

By Robert Briggs, C. E.

[Abstract from remarks at the meeting of the Franklin Institute, Nov., 1876.]

The attainment of some degree of accuracy in the measurement of intervals of time has been, in every age, one of the tasks which has been accepted by all conditions of humanity, as a desirable and necessary labor, to be followed to a certain result. As mankind emerged from barbarism, each race came to appreciate the value of defined periods of time, and adopted those most obvious; and sought carefully for means of comparing and dividing them. That time could only be measured by the recurrence of some movement in nature, was the immediate deduction; the period of a day and a night, with the recurring order of sunrise and sunset, light and darkness, of the demand of human nature for sleep or food, formed an obvious interval, or unit of time. Other natural phenomena of movement follow in the sequence of days. The moon marks out a certain number of days, at the expiration of which the new or full moon will occur, and in narrating or anticipating any events of life, the longer unit of the month became the measure of time for the semi-barbarous races. But the recurrence of the seasons was quickly discovered to be a more important event in human economy, than that of the months, and some of the earliest recorded efforts of civilization were directed to the determination of the length of the year, *measured* in months or in days. In about the same latitude as that in which we live, the scientific men of nearly 3000 years since, magi or magicians, came to estimate with much accuracy the number of days, and parts of days, which formed the cycle of the year. Careful observation of the movement of the heavenly bodies showed, that at the end of about 365 days, as they determined it, the phenomena of altitude of

the sun recurred, the positions of constellations with regard to midnight, repeated themselves; and the recurrent interval of a year's length of time was established by the movement of these bodies. The phases of the moon were measured out in days and parts of days by those same magicians, and discovered not to be in even numbers, while the repetition of the moon's movements did not make even number divisions for the year. But these physical intervals were all so well marked, as to have been adopted by communities and nations, and used for prolonged periods as their units in the transactions and in the records of life. The assimilations of these communities, or the establishment of empires, or conquests of nations, the attempt to use all these units at once, and preserve the advantages and the established custom of usage for each, led to many devices for making them intercommensurable with each other, without fractions. The relics of these devices have come to us in the Julian and Gregorian systems for compensation of the fraction of the day in the year's length, and in the arbitrary division of the year into twelve months or moons of irrational value, possessing no exact relationship to the periodicity of the moon's apparent motion around the earth. The week of seven days, which we have as one unit of time, is merely, beyond its theological relations, a notation of sevens for aggregating units into numbers, in the same way that ten is a notation of our decimal system, only that the system of sevens is not carried beyond its first power.

All the measurements of time depend on movements, and when it was thought desirable to use for reckoning or statements, any definite part or fraction of a day, some other movement of uniformity than that of the heavenly bodies, was sought, whose recurrence some number of times in a day, with regularity, would allow the desired division to be valued. It is obvious that this movement of recurrence must be so small, that some number of its repetitions should indicate the length of the desired division or fraction of a day. The day has come to us from a remote antiquity as divided into 24 hours, which are again subdivided into 60 minutes, and yet again, the minutes are subdivided into 60 seconds. Of these divisions, that into 24 hours, seems purely arbitrary, and no reason can be suggested for its derivation; but the notation of 60, in this case a complete notation to the second power, is unquestionably based upon the assumption that, given any unit of measurement in habitual use, the 60th part is so

small that further division is uncalled for. The same assumption is made by us in the United States as to a percentage, or hundredth of anything. The duration of time of a second, however, when considered by itself, is a very considerable period. Perhaps the readiest appreciation can be had by comparison with the time of a pace or step, which is from one and a half to two steps in a second, in ordinary walking. Rates of progress which correspond to from $2\frac{1}{2}$ to $3\frac{1}{3}$ miles in an hour. This exhibition of the length of a second admits of comparison with the movement of the individual, and gives $3\frac{3}{4}$ to 5 feet of lineal dimension as the length of a second. The German measurement of distance is by the hour, which corresponds to three English miles, and represents the distance to be walked in the given time.

These brief remarks in prelude have been made to impress it firmly on the minds of my hearers, that *time* is a condition of movement, and its measurement in all cases depends on the accuracy of some phenomena incident to motion. No division of a unit of time can be made except by establishing some smaller unit. Given one series of recurrences, it is necessary in order to effect a division or measurement of any interval between any successive part of the series, to possess another order of recurrences, smaller than the first.

In effecting this end, every species of recurrent motion has been employed. The water clock, which produced by the constancy of flow of a stream of water a definite number of revolutions of a wheel in a day, was one of the earliest methods of comparative merit and success. Balance wheels and fan wheels were employed as means of production of regular speed; in fact, every species of running motion was availed of to form bases or units of length. Little real progress, however, was made in horology, until the modern revival of science, when, about four hundred years ago, the isochronism of the pendulum, and of the spring combined with a reciprocating balance, was brought into action to regulate the clock and the watch.

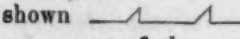
The pendulum and the spring have remained the most accurate of measures. The ingenuity of modern science has been expended in perfecting them, until the astronomical clock and the chronometer have become marvelously accurate as standards of uniformity and precision. Day by day the second's pendulum of a clock of the higher order of construction, spaces off its 86,400 steps, all of the same duration, until at the expiration of this immense number of beats but a fraction of a second of gain or loss will have taken place.

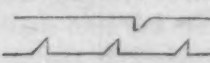
At this point the limit of accuracy attainable by adjustment will have been reached; but by computation even this small error is to be removed. Astronomy has demonstrated that the days vary in length at different seasons of the year, and the amount of such variation has been calculated, so as to establish the length of the *mean day*, which is supposed to be of uniform length. The astronomical time of day can be found by observation of some of the heavenly bodies with great accuracy; by the *equation of time* the mean time can be derived with equal accuracy, and the gain or loss of time by the clock can be determined; and the gain or loss in any twenty-four hours is known as the *rate* of the clock. The uniformity of *rate*, the equality of the variation each day, thus becomes the standard of excellence of the clock, and the adjustments of the pendulum having reached the limit of careful workmanship, the compensation for the error of *rate* remaining, can be effected by dividing up the *rate* amongst the seconds which have passed at any assumed instant.

These steps of seconds, it is thus shown, have become very definite and accurate divisions of the day—they can be accepted as absolutely equal intervals of time—just as years are equal to each other and as mean days are defined parts of equal lengths of a year—but the second is yet indivisible except by guess. The movement of a clock during the day is apparently a uniform one, yet it is composed of escapements of seconds, and the clock actually comes to rest during a part of each second to allow the second to be completed and pass away.

Now the same seeking for precision that divided the day into hours, the hours into minutes, and the minutes into seconds, has sought the division of the second into smaller parts, through the establishment of a movement of uniformity which shall have so short steps *as its units*, that each step of itself shall be imperceptible in the resulting motion. There are many ways of effecting this. A spring or falling weight will put in motion a train of wheels, and the uniformity of speed may be regulated by constant-resistance-friction-fly wheels, or fan wheels operating in air or water, or may be governed by the circular pendulum (or governor of the machinist), and a uniformity of motion of more or less completeness can be thus secured. It is not necessary that the uniform motion for this purpose should be at a definite speed, just so fast each second, but advantage can be taken

of the principle I have before alluded to, when describing the way of getting the *rate* of a clock. Suppose the nearly uniform motion be imparted to a cylinder or riband on which a line is traced; now if any mark or prick or indication is given along this line, at the instant of passage of each second, it will follow that the line can be divided up to indicate the parts of a second with much accuracy.

The real method now employed in astronomical observations is as follows: A train of wheels put in motion and regulated in some way to the requisite uniformity, gives rotation to a barrel covered with paper (or draws a paper riband), on the surface of which a pencil is tracing a line (in the case of a barrel the pencil is made to have a small side traverse or feed, so that the line becomes a continuous screw thread), and each second a mark is made on or near the line by the action of the (seconds) pendulum of the astronomical clock. In point of fact the pencil which makes the line is generally made to give the indication of the length of the second, by having a sudden side-wise movement imparted to it, and the line described on the surface of the barrel, in lieu of being a straight one, is notched or jagged as shown  . The connection of the movement of the pencil to the pendulum is thus effected. At some convenient point on the rod of the pendulum, more suitably near or at its lower end, a pin is allowed to project. The rate of motion of the pendulum is, of course, greatest as it passes the perpendicular line, and at this place the pin comes in contact with a lever-key, which it depresses into a mercury cup and establishes the circuit of a battery. An electro-magnet is thus excited and its armature attracted. The pencil which traces the line on the revolving cylinder is, by the construction of the apparatus, arranged to be moved side-wise by the action of the electro-magnet, and the resulting line will become as shown with a notch for each second of time. A similar arrangement of pencil and electro-magnet allows an astronomical observer to record the exact instant of an observation. The second pencil is employed in tracing another line parallel with the *seconds* line, upon the same cylinder or riband, and the astronomer, by touching a key (like the key of a Morse telegraph), produces a notch similar to those indicating *seconds*. The appearance of these



lines and notches is shown on the accompanying sketch, and the relative position of the notches makes it evident in what way the por-

tion of second, from the instant of observation to the whole second, can be measured with great accuracy.

The oldest method of giving uniformity of motion to a train of clock-work was by means of a *fly* or small fan wheel, but beside the difficulty of adjustment, no very close approach to *equality* of movement can be had in the use of the fly, although a fairly uniform motion may be obtained during any one second, or even for several consecutive seconds. In fact before the discovery of the constant motion of the pendulum, which is ascribed to Gallileo, and its application to an escapement, which is ascribed to Huyghens, the *fly* was the usual regulator of the clock. Such a clock required to be *set* from day to day—it must be compared and made to correspond with a sun-dial, or with some other natural indication of exact time at a given moment. The chronograph which I have described is *set* from second to second, by the marking of notches at the end of each interval. Probably most of my hearers have examined the works of the common music box and discovered that its regularity of motion while playing a tune is due to the fly. A very little practice in the use of this method of attaining uniform motion demonstrates its unsatisfactory character. The resistance from the friction of the bearings of the rapidly rotating *fly*, and of the train wheel work which impels it, bears so large a ratio towards that which is derived from the action of the wings of the *fly* in the air, that the variation in the first resistance which constantly occurs in use, is often greater than the regulating power of the latter resistance. By no means the least difficulty in regulation with a *fly*, arises from the change of density of the resisting medium—the air, which, between 30° and 80° Fah. of temperature, and between 28 inches and 30 inches of barometric pressure, will give a greatest variation, of nearly, as four is to five in density, and changes the rate very materially. The *government* of motion by some one of the forms of the rotary pendulum, which of itself may be made isochronous, or in other words to rotate in equal times, whatever the position of the balls, whether they resist gravity more or less modified on a spring, has been frequently attempted, and often with much success. The method is open to two objections, one in principle—that all rotary governors operate by bringing into action or relieving some resistance *after* the governor has been either accelerated or retarded, when the effort always surpasses the absolute requirement, and the speed attained pulsates between too fast and too

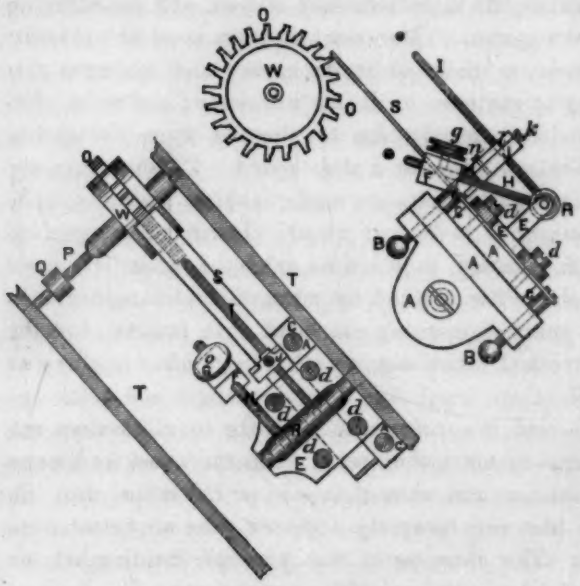
slow, never reaching exact uniformity; and the second in practice—in that rotary governors call for such dimensions of parts, and if acting by gravity such adjustment in position as to lose in a great degree the advantage of portability.

Without entering into the consideration of this subject of government by the rotary pendulum any further, I will proceed to describe another method which has given admirable results. The Hipp spring regulator has for its principle of action the uniform vibrations of a body, which, transmitted to the air, give a musical sound of some definite note. The lectures on acoustics, by Prof. Houston, last season, have familiarized most of my hearers with the knowledge that the arms of a tuning fork, in emitting its musical note, make a certain number of vibrations each second. The sound may be louder or less pronounced, but the same fork always gives out the same note, that is, makes just so many vibrations in a given time—same as a pendulum, at any certain length, always makes just so many beats in a second; the loudness of the sound being a condition of the amplitude of each vibration. Thus, a spring of certain length and thickness, which makes 528 vibrations each second, will produce the musical note $\bar{c}$ of the gamut. These musical beats must be perfectly regular in their time, or their ability to impart and maintain the vibration belonging to any note to the air will cease; and it is, consequently, easy to detect by the ear the instant when the spring ceases to be musical, to give out a clear sound. These extremely small but perfectly regular beats are made, in Hipp's *chronograph*, to allow the escapement of a toothed wheel. I will refer again to the lecture of Prof. Houston, in which he exhibited what is known as "Savart's Wheel." The method by which this philosopher discovered that the beats of a spring coincided with musical sounds, was to revolve a toothed wheel against the free end of springs of different sizes. He then found that a certain length and thickness of the bar which formed the spring was requisite to allow the teeth —each one of them—to touch the spring when the wheel had some certain speed of rotation, and when the speed of the wheel and the dimensions of the bar were properly adjusted, then a musical note would be emitted. The converse of this principle holds good, as Hipp's chronograph demonstrates, with a given spring, a toothed wheel, impelled by a certain force of small amount, by means of a spring or weight, will pass the free end of a spring, which may be

made adjustable in length so as to give any desired number of vibrations in a second, by the escapement or passage of a tooth at each vibration. Any uniform vibration whatever, emits or produces a musical sound. The only condition of a note of music is that of uniformity of time of vibration, while a musical *instrument* consists in certain relations of the numbers of vibrations of two consecutively sounded notes, so that their vibrations shall coincide at short intervals, so that the ear *measures* the length of one set of vibrations by that of another set of vibrations. This measurement, by coinciding vibrations, is what constitutes the mental appreciation of melody.

But a perfectly uniform series of vibrations will produce what will be recognized at once as a clear and distinct musical note, and 528 of such vibrations each second will give the note of $\bar{c}$, now accepted by musicians as the *pitch*. A tuning fork adjusted to give this note will produce no other, however hard or lightly it may be struck.

FRONT VIEW.
Section between the Plates.




PLAN (Diagonal Projection).
HIPP'S CHRONOGRAPH.
Scale, One-half Size.

The accompanying figure shows the escapement of a Hipp's chronograph, in the Swiss department of the U. S. International Exposition. As the spring and its adjustable parts were placed diagonally at an angle of 45°, it was necessary, in making a top view, which should not be distorted, to *project* a plan on the *diagonal*.

This unusual arrangement of drawing will call for a somewhat close examination to be understood, but it really presents a correct plan of the parts. The same letters on the several parts shown on view or plan, refer to the same pieces. The spring, indicated by *S*, is clamped to a rocking saddle *A*, which is secured to the plate *T* by the large screw, the head of which shows in the view, and is adjusted by the set screws *c c*, which impinge on some studs *B B*, that are set in the plate *T*; by this means the end of the spring is adjusted for contact with the escapement wheel *W*. The clamping piece for the spring is the rider *E*, and the four screws, *d d d d*, effect the clamp. This rider *E* carries a spindle *R*, which has two arms, *I* and *H*. Upon the arm *H*, there is placed a sliding head *J*, which is set when desired, on the arms by the screw *k*. This head carries a bit *m* of rubber or hard cork, which rests upon the spring *s* (*m* is clamped to *J* by the plate *l*, held by the screw *n*), and only that part of the length of *S* which projects beyond *M* is free to vibrate; consequently, the moving of the head *J* will control the number of vibrations by lengthening or shortening *S*. The second arm, *H*, carries the weight *F*, which is adjusted in place by the screw *G*. The action of this weight is to give the proper value of the pressure of *M* and by increasing the labor of the elasticity of the spring to lengthen the time of vibration. *O O* are the teeth of the wheel, *P* is the shaft, and *Q* is the pinion which gears into the train of impelling wheel-work. In the instance here chosen there were twenty-one teeth to the escapement wheel, and the driving mechanism was 1 to 7 for the first pinion and wheel, and 1 to 10 for the second pinion and wheel; while two revolutions each second, of a pair of rollers, drew forward a riband, which then received the mark of the second's interval of time from an independent pendulum clock. It follows that this spring would make about 735 beats per second. $\bar{f}$ sharp of the scale is about 745 beats.

In practice with a Hipp spring escapement the tooth does not rest upon and vibrate with the spring, so as to form a positive escapement each vibration, but the spring is adjusted just to clear the teeth of the wheel when the wheel is at rest, and the air between the teeth becomes the controlling agent, checking the rotation but not stopping or giving an absolute recoil at any instant.[1] The drawing

[1] Prof. Hilgard says: "Although it is a good adjustment for the spring to be just clear of the tooth when at rest, the extremity of the spring actually vibrates above

shows the position of the spring in the later instruments of Hipp's own construction.

From information derived from Prof. J. E. Hilgard, U. S. Coast Survey, I am able to say that much experience has been had in that Department in the use of Hipp's chronograph. They have three sizes; the smallest is regulated by a spring making 1000 double vibrations per second; the medium makes 560; the largest only 280 in the same time. A sheet from a cylinder chronograph, the barrel of which is 20·3 inches in circumference, and having upon it 60 seconds for each revolution and the lines of 99 minutes, shows the entire deviation in the entire time to be one and a half seconds. The cylinder machine presents great advantages in exhibiting the deviation from perfect uniformity, or the failure to effect a perfect adjustment of second's lengths with the revolutions of the cylinder. Thus the sheet in question shows that for 33 minutes there was a regular gain of one second during the time, the line of second marks advancing so to form a straight line inclined to the axis of the cylinder, and gaining one second's length in 33 revolutions; thus exhibiting that each minute was one-thirty-third of a second too long. The regularity of this condition throughout the entire revolution, second by second, shows that each second was 1–2000th the part too long,—the half of a vibration of the shortest regulating spring in error.

In the Appendix, No. 18, of Coast Survey Report (1872), will be found a method of adjustment of the length of spring while the chronograph is at work, proposed by Mr. Wm. Eimbeck, sub-assistant U. S. C. S. Mr. Eimbeck mounts the bit *M*, which adjusts the length of the spring *S*, with all its parts (which he modifies considerably), on a sliding frame (in lieu of on the rider *E*), which frame he moves endwise by a screw. The modification of the parts referred to, consists mainly in substituting a spring for the weight *F*, which spring is adjusted by another screw. As a result he was able to change the rate of the machine instantly—while running—to from one revolu-

---

and below the point of the tooth where the chronograph is running; now whenever it strikes down clear of the tooth, the train will go on accelerating until the point of the next tooth will strike the spring as it comes down. This will check the train for the instant, after which the spring vibrates freely again until another, similar, acceleration has been reached. Each of these contacts makes a perceptible beat in the hum of the note. The more nearly the train is running to the time of the spring the less frequent they are, but of course the train *must* be always over-driven."

tion to two revolutions of the cylinder per minute—thus attaining the number of vibrations of the spring per second as two to one. The number of turns of the screw, in making the change, was determinable, and once found, "the various adjustments could be made without the slightest interference with the running of the chronograph." According to Mr. Eimbeck "the point of pressure upon the governing spring, when once adjusted, should remain perfectly constant."

While the chronograph now described has heretofore been applied only to use for astronomical observations, and to the determination of the velocity of projectiles,[1] I have brought it forward at this time principally to consider its application to some demands in mechanical industry and engineering science. It is well known to engineers that the ordinary reciprocating steam engine gives an irregular motion controlled first by the fly wheel which is alternately the driver and the driven during parts of each single stroke, and next by the governor, which is always endeavoring to slow the engine when it runs too fast, and to accelerate it when it runs too slow, and is totally inefficient in *preserving* equality of movement. It has long been desirable to possess some instrument which would exhibit the inequalities of movement of an engine. For the purpose of spinning fine yarn, for instance, it has come to be thought that the requisite uniformity of motion can only be derived from a water-wheel. A main pulley, whose surface speed will vary as 4 to 5 during the stroke and as 4 to 5 again in consecutive revolutions when running accurately 60 (or some other definite number of) revolutions per minute, is nearly as unsuited to produce nice work as such a pulley driven by an engine, whose speed shall vary as 16 to 25 revolutions per minute.

The principle of construction of a chronograph for engine testing is that of comparison of two motions, one of which shall be uniform and the other irregular or variable. The usual method is to rotate a paper covered cylinder at uniform speed of rotation in front of a pencil which is made to travel by a screw or feed, driven by the engine (or motor being tested). Suppose the cylinder to be 10 inches in circumference and to rotate by its own power once in a revolution of the engine, and suppose the pencil to traverse 10 inches in the

[1] Prof. Hilgard informs me "that I once had a chronograph built for the Navy ordnance department, on which the seconds were 30 inches long—correct to, say, 1-5000th of a second—it would only run five minutes at a course."

same revolution, being driven by the engine itself, it will then follow that the path of the pencil on the paper, when the covering of the cylinder is unrolled or developed, will be a straight line, if both motions are perfectly uniform. Whatever deviation from a straight line may be found in the tracing, will indicate the irregularities of speed, and establish their exact amounts. This same condition subsists, without regard to any relation of rotation of the cylinder to that of the engine, and the same principle holds good if the uniform motion be given to the traversing pencil, and the cylinder be driven by the motor to be tested. Where the engine marks each revolution automatically on a cylinder revolving at a definite rate, the variations of consecutive revolutions will be indicated by the position of the marks on face of the cylinder.

Not only the rotating engine requires this chronograph test, but it is equally, if not more essential for the exhibition of performance of the pumping engine of the non-rotating type. The chronograph of Gen. Morin,[1] with a fly regulator, was employed in 1843-4 in showing the velocities of piston for the Cornish engine at Old Ford (Pole on the Cornish engine, fo. 210, *et. seq.*), and a similar discussion should accompany each scientific investigation of a pumping engine. With this indication of the capability of the Hipp chronograph for practical mechanical use, I will close my remarks upon it.

It is proper, however, that I should, by way of comment, allude to the successful measurement of yet smaller intervals of time by Mr. Robt. Sabine. Mr. Sabine uses the constancy or uniformity of flow of an electric current produced by a given battery, and encountering a definite resistance; and by its means has measured, with certainty, less than the 1-100,000th part of a second of time, and with his apparatus has actually measured the duration of a blow upon an anvil. In the JOURNAL for December will be found a

---

[1] See Nouvelles Experiences sur la Frottement par Arthur Morin, Capt. Art., fo. 19, *et. seq.*, for descriptions and drawings of this apparatus; and Report British Association, 1844, fo. 90, for circumstances of its application.

"A circular disc covered with card or paper, is made to revolve with uniform motion by means of a clockwork regulated by air valves. Upon this disc a revolving pencil whose motion is caused by, and corresponds with, that of the body whose variable velocity is to be measured, describes a curved line; from this curve the velocity may be ascertained."

paper [taken from *Engineering*, London, Oct. 27, 1876] by Mr. Sabine, giving the details of a series of experiments; to this paper I refer my hearers; and for a more complete description of Mr. Sabine's methods, a reference to the original paper in the *Philosophical Magazine* for May, 1876, will be advisable.

---

## TONOMETRY.

By A. J. Ellis.

[From the *Athenæum*, London, December 2d, 1876.]

The Problem of Tonometry is: given a sustained musical tone to determine the number of vibrations made in one second of time by each particle of air, conveying the undulation to which the sensation of sound is due. By a vibration in France is meant the motion from the extreme position on one side, to the extreme on the other, like the single swing of a pendulum. In England, and now in Germany, by a vibration is meant the motion from the extreme position on one side, to the return to the same position, like two swings of a pendulum. *This* will here be always understood by the term vibration, and the former will, when necessary, be distinguished as a simple vibration. Tones are simple when the motion of the air follows the law of a pendulum; and compound in other cases. Compound tones are heard as if a certain number of simple tones (called partials) were sounded simultaneously. In this case the pitch is the number of vibrations made in one second by the lowest partial.

The old attempts at tonometry were made by a monochord, which was horizontal, or, much better, vertical,[1] stretched by a weight mathematically determined by the transverse section and specific gravity of the string, and limited by a fixed bridge at one end, and a movable bridge at the other. The pitch could then be calculated from the measured length of the string. More recently the siren, in which a perforated plate was driven by a stream of air with increasing, but constantly measured velocity, producing a constantly higher note, has been extensively used. The pitch of the given note had

[1] Smith's "Harmonics," and General T. Perronet Thompson's "Just Intonation."

to be determined by the estimation of the ear as to when the monochord or siren gave a note identical with that under examination. All these methods are liable to numerous errors, and practically their results cannot be depended on to 10 vibrations in one second. Other methods were still worse.

Tonometry was first placed on a scientific basis in a badly written, but extremely valuable, little pamphlet of 80 pages and 4 lithographic plates, published at Essen, 1834. This pamphlet was entitled "The Physical and Musical Tonometer (*Tonmesser*), which proves by the pendulum, visibly to the eye, the absolute vibrations of tones, and of the principal general of combinational tones, as well as the most definite exactness of equally tempered and mathematical chords, invented and executed by Heinrich Scheibler, silk-ware manufacturer in Crefeld." [Crefeld is a town of Rhenish Prussia, twelve miles north-west of Düsseldorf, celebrated for its silk factories.] The principle upon which Scheibler proceeded was this. Tones which differ by a small amount "beat" together,—a very familiar phenomenon—varying from a slow wave to a rapid rattle; and the number of beats in a second is precisely the same as the difference in the numbers of vibrations which the two tones make in a second. A tuning-fork will also beat with an imperfect octave above it, and then the number of beats is the difference between the number of vibrations of the upper tone, and double the number of vibrations of the lower tone. Thus 256 and 259, or 256 and 253, beat three times in a second; and 256 and 515, or 256 and 509, also beat three; that is, the beats do not show whether the upper note is too sharp or too flat. This has to be ascertained by flattening the upper tone (placing the upper tuning-fork under one's arm for a minute or two is sufficient); if then the beats diminish in number, the upper note is brought more in tune, and was too sharp; if the beats increase in number, the upper note is brought more out of tune, and was too flat. For compound tones, other intervals can be selected, as shown below.[1] Then two forks being tuned roughly to (say) A on the first line on the bass staff, and

[1] Let the ratio of any perfect interval be $m : n$, $n$ being the greater number. Let two compound tones, having the vibrations $y$ and $z$, and audibly possessing the $n$th and $m$th partials respectively, form exactly this interval, then $m : n :: y : z$, or $mz = ny$, and no wave is heard. If they do not exactly form the interval, the difference of $mz$ and $ny$ gives the number of "beats of error," as distinguished from the "rattle of the beating partials," which always exists more or less distinctly in "reedy" tones.

the A above it, the upper A is flattened till it beats exactly 4 times in a second with the lower. (This is the easiest number to count. Generally either a very exact compensating metronome has to be used, or the beats must be counted through 10 to 100 seconds, and then the number of beats divided by the number of seconds. Less than 1 and more than 6 beats in a second are difficult to count with certainty, more than 8 almost impossible.) A third fork is now tuned 4 beats (in a second, as must be always understood) sharper, and will give the exact octave of the lowest fork, without any wave or error. Then proceeding downwards by 4 beats at a time we reach a fork which beats sharp 4, or less than 4, times with the original fork, and these beats are accurately counted. The sum of all the beats of all the forks, two and two, from the lowest to the highest, is necessarily the exact number of vibrations of the lowest, because these beats represent the number of vibrations to be added to the lowest in order to produce its octave, the highest, which has twice as many vibrations. Thus, the absolute pitch is known of all the forks used, and forks can be tuned to any intermediate pitch by less than 4 beats in a second. The construction of such tonometers of forks, large in size, never touched by the hand, kept at a constant temperature, and anxiously observed and re-observed, is a matter of great difficulty. Scheibler's original tonometer had 52 forks extending from A 219⅔ (that is the note called A, and making 219⅔ vibrations in a second) to A 439⅓, but proceeding by unequal numbers of beats. Koenig, of Paris, subsequently improved on this by making one of 65 forks from C 256, to C 512, proceeding by 4 beats, and added two other forks F 341⅓, and A 426⅔. This is priced in his catalogue of 1865 at 2,000 francs, or 80*l.* Scheibler's own tonometer was made in 1834, by Kämmerling (long since deceased), in Crefeld, for sixty dollars, or 9*l.*, paid at time of ordering (*Tonmesser*, p. 80).

These instruments, with proper precautions, do excellent work. But they are cumbrous, costly, excessively variable with temperature, extremely mild in quality of tone, which prevents verification by any interval but the octave; with notes difficult to sound more than two at a time, and difficult to flatten and restore to pitch rapidly. These inconveniences are practically overcome by the tonometer made by Georg Appunn and Son (of Hanau, Hessen-Cassel, near Frankfort-on-the-Main), now in the Loan Collection of Scientific Apparatus at South Kensington, and priced, as I find on inquiry (it is as well to

state that I have none but a scientific interest in the apparatus) at 360 German marks, or 18*l.*, without the blowing apparatus, which adds about 6*l.* or 7*l.* more. It is of small and comparatively convenient size, and its tones are not nearly so much affected by change of temperature as those proceeding from tuning-forks. The notes are extremely reedy in quality of tone, so that the 16th partial can be made effective, and hence all intervals used as verifications. The notes are also easy to sound and to damp in any number at a time; and to flatten, any one separately and instantly or gradually, by 1, 2, or even 3 vibrations, and to restore immediately to the former pitch. This last is one of the most important properties of the instrument. It consists of 65 harmonium reeds, actuated by pulls numbered 0 and 1 to 64, which when pulled out completely give the true tone, and when gradually pushed in, gradually flatten the tone. The pitch is from c 256 to c 512, increasing regularly by 4 vibrations.

Using this instrument to measure forks, I found great discrepancies between the numbers shown and the numbers stamped on the forks. For my own satisfaction, therefore, I verified the instrument as follows. First I counted the beats with a pocket chronometer between pulls 0 and 1 for 15 seconds, and found them 60, or 4 in a second. Next I counted the beats between each pair of the other adjacent pulls for 20 seconds, and found them always 80, or 4 in a second. Hence the whole increase was 4 times 64, or 256 vibrations. I then examined, first, the usual consonances on the instrument, consisting of 1 Octave 1:2, 11 Fifths 2:3, 11 Fourths 3:4, 10 major Thirds 4:5, 9 minor Thirds 5:6, 4 major Sixths 3:5, 4 minor Sixths 5:8; secondly, the septimal consonances, 6 sub Fifths 5:7, 4 super-major Thirds 7:9, 8 sub-minor Thirds 6:7, 3 sub-minor Sevenths 4:7; and thirdly, the usual dissonances, having audible identical partials, 7 major Tones 8:9, 5 minor Tones 9:10, 4 diatonic Semitones 15:16; or 87 just intervals on the whole. For every one there was the proper rapid rattle of beating partials, but not the slightest wave of error in the identical partials. This wave was, however, instantly produced by flattening the upper reed, and made to disappear by flattening the lower reed at the same time to the proper extent, and to reappear by flattening the same more. I have, therefore, a mechanical guarantee that every one of these intervals was correctly represented on the instrument. But every one of them separately proved, after counting the beats, that the lowest tone made 256 vibrations in

a second, and the whole set by their perfect agreement proved that the beats had been correctly counted.[1] The introduction and extinction of the beats of error were often very remarkable. Thus the diatonic semitone, pulls 11 and 16, with 300 and 320 vibrations, when the upper note was flattened, beat in error with 4,800, and the same slightly altered; that is, a D *sharp* above the ninth leger line above the treble staff, and the same slightly altered. This slow beat of error was distinctly separable from the rapid rattle of the beating partials, including the lowest and strongest. By conscientiously trying every one of these 87 cases, I have convinced myself of the perfect trustworthiness of the instrument, and those to whom I have shown some of them, have been equally convinced, among whom I need only mention as most competent to decide, Mr. A. J. Hipkins of Messrs. Broadwoods, and Mr. E. Greaves of Sheffield, a large maker of tuning-forks for Messrs. Broadwoods, and the whole music trade, who has now accepted the 256, 384, and 512 of Appunn's instrument, as absolutely correct, and copied them on forks.

An examination, by means of this tonometer, of a number of standard forks, developed some remarkable results. [It is stated that the pitch of the Paris opera, 1699, was A 404, C 480·44, and it is quoted here as the lowest pitch on record, but the correctness of the statement is questionable.] Handel's fork, 1751, gave A 426·4, C 507·14—this fork was used at the Foundling Hospital, when the Messiah was performed, and a contemporaneous note stated, "Antient concert, whole note higher; Abbey, half tone higher; Temple and St. Paul's organs exactly with this pitch." A series of other forks from the best authorities, proved to vary in small amounts from their supposed values, and compared when reduced to C 510·1, 512, 515·82, 517, 517·25, 518·52, etc.; while a French normal, which should have been A 435, proved A 439, C 522·06. Close to this figure comes

[1] Let $x$ be the vibrations of the lowest note, $p$ and $q$ the beats added by pulls $P$ and $Q$, found by counting, so that the reeds actuated by $P$ and $Q$ gave $x+p$ and $x+q$ vibrations, and let $m:n$ be the ratio of the interval. Then, by the preceding foot-note, $n\,(x+p)=m\,(x+q)$, or $(n-m)\,x=m\,q-n\,p$, which gives the value of $x$ in each case. Thus pulls 10 and 47 give a Fifth 2 : 3, and counting gives $p=4\times10=40$, $q=4\times47=188$. Hence $(3-2)\;x=2\times188-3\times40$, or $x=256$, and so for all the 87 cases. Had there been any error in counting, it would have been detected by one or more of these cases not giving $x=256$. Of course, these perfect intervals render the instrument invaluable to any teacher of musical acoustics.

the fork of Sir George Smart, c 521, Messrs. Broadwoods' "low pitch" c 523. The "Stuttgart pitch" c 523·25, the Vienna orchestra, 1834, c 524·29. [The Soc. of Arts' standard, which is theoretically c 528, but which was never made, can be compared to these last results.] And finally, there was tested a series of higher forks, Broadwoods' medium c 535, and others, of which Sir M. Costa's Philharmonic Wind Band Concerts of c 542·5, and Broadwoods' high-pitch c 545·2 are examples.

The above statements having been carefully read over to Mr. A. J. Hipkins, he concurs in the accuracy of all that relates to himself, and to the forks in possession of himself and Messrs. Broadwoods, which he obligingly brought to me for measurement. It is hoped that the above measurements, and especially Appunn's convenient tonometer, a copy of which should be in all musical centres, will contribute to settle the question of Standard Pitch in England. It will be seen that the real French normal A 439 = c 522, and Scheibler's A 440 = c 523¼, and Messrs. Broadwoods' "low pitch," c 523, seem to unite the greatest number of pitches in actual use.

---

## CERTAIN POINTS IN THE DEVELOPMENT AND PRACTICE OF MODERN AMERICAN LOCOMOTIVE ENGINEERING.

By Francis E. Galloupe, S.B.

Continued from Vol. ciii, page 28.

*The Efficiency of the Heating Surface* is equal to the ratio of the difference of temperature of the hot gases on first coming in contact with it, and on leaving it, to the amount of heat transmitted by it to the water; or, calling $T_1$ the temperature of the hot gas at first, $T_2$ its final temperature, and $t$ the temperature of the water, its efficiency, $e = \frac{T_1 - T_2}{T_1 - t}$.

The efficiency of the furnace is the proportion that the available heat from one pound of fuel bears to its total heat of combustion. The laws of combustion are fixed and definite, and the boiler should be so proportioned as to conform to them. With the heating surface, however, it is found that no two portions have the same efficiency. The efficiency depends upon a number of conditions, the extent of

surface, its position, the nature and thickness of the conducting material, the difference of temperature, the time allowed for the transmission, the nature of the heating substance, whether heated gas, flame, or incandescent fuel, and the manner in which the heat is communicated, by conduction or radiation. In regard to the first two of these it has been found[1] by Mr. Armstrong, that "a cubical metallic box, submerged in water, and heated from within, generated steam from its upper surface more than twice as fast per unit of area, than it did from the sides when vertical, and that the bottom yielded none at all." From this experiment, and others by C. W. Williams, and D. K. Clark, upon the diminished heating effect of successive portions of the tubes, it is found that the crown sheet and furnace tube plate are the most efficient, a square foot of the fire-box area being equivalent to three of the tubes. The latter are placed in vertical rows, with $\frac{5}{8}$ inch water space between them, and from the above, it will be seen that the bottoms of the tubes, or one-fourth of their circumference, have, practically, no heating effect, while the sides together are only equal to the top, so that, really, we may consider but one-half of the tube area as effective as the fire-box. The equivalent heating surface in the tubes would therefore be but 463·6 instead of 927·3 square feet.

Practically, in estimating the heating surface, three-fourths of the tube area are included, neglecting only the bottom, so that in this boiler we may correct the value of the total heating surface found, and by doing this we have the *effective* heating surface,

$$= \tfrac{3}{4} \times 927{\cdot}295 + 97{\cdot}59 = 695{\cdot}47 + 97{\cdot}59 = 793 \text{ square feet,}$$

which agrees very well with that given by the rule, or 742.

The theoretical consideration of heating surface, and the transfer of heat through it, forms one of the most profound and complex, and at the same time interesting, subjects in physical science. I shall then be obliged to state here only results, without giving, in extent, the reasons on which they have been based. The rate of conduction of heat through a boiler plate, or the number of thermal units transmitted per square foot of area per hour, is dependent upon the rate at which the temperature varies along a line perpendicular to the section through which the heat is transferred,[ii] and upon the

---

[1] Tredgold, on the "Steam Engine."

[ii] Rankine.

resistance of the material to its transfer, or upon what is called the coefficient of internal conductivity.

The quantity of heat conducted is directly proportional to the area of the conducting surface, the length of time, and difference of temperature between the two sides of the plate, and inversely as the thickness of the plate, and as the coefficient of resistance of its material, if by this we denote the reciprocal of the coefficient of conductivity. Now the resistances are made up of three factors; that of the transfer of heat from the hot gases to the plate, upon one side; the internal resistance of the plate; and that of the transfer to the water upon the other; and denoting these by $r$, $r^1$, and $r^{11}$, respectively, we have Rankine's formula for the rate of conduction per square foot of heating surface, $K = \frac{T^1 - T}{r + r^1 t + r^{11}}$, $t$ denoting the thickness of the plate. Since the external resistances greatly exceed the internal, the latter is neglected, and in a formula based on one deduced by M. Peclet, and agreeing with the best practice, Rankine gives the external resistance, $r + r^{11} = \frac{a}{T^1 - T}$, where $a$ is a constant, the mean value of which is 180. Assuming that the hot gases escape from this heating surface at a temperature of 600°, which is the maximum, and also the temperature which would produce the best natural draught, and that the temperature of the fire is 3044° Fahr., the rate of conduction through a square foot of plate is found to be $K = \frac{(T^1 - T)^2}{a} = \frac{(3044 - 600)^2}{180} = 33{,}184$ thermal units per hour. Or, if the heat was fully utilized, since the temperature of the escaping gases cannot be lower than the temperature of the water, and this, for 140 lbs. steam pressure, is 360·595° Fahr., the rate of conduction could not be more than

$$\frac{(3044 - 361)^2}{180} = 39{,}436 \text{ thermal units per hour.}$$

The efficiency of the entire heating surface, obtained by integrating the value of $\frac{T_1 - T_2}{T_1 - t}$ for each minute area $ds$, of the heating surface, and inserting the relations found in the formula explained above, can be proved to be equal to this expression, given by

Rankine, $e = \frac{S}{S + \frac{a\, c'^2\, W^2}{H}}$ in which $a$ is a constant; $c'$, the specific heat of the gas at constant pressure; $W$, the weight of gas given out in an hour; $H$, the total expenditure of heat per hour, and $S$, the number of square feet of heating surface. Since the amount of heat $c'^2\, W^2$ is proportional to $V_0^2\, F^2$, where $F$ is the number of pounds of coal burned in the furnace per hour, and $V_0$ is the volume of air at a temperature of 32°, supplied per pound of fuel, Rankine represents the efficiency of the furnace, or the ratio of the available to the theoretic evaporative power of the coal, by an equation of the following form: $e = \frac{E'}{E} = B\, \frac{S}{S + A\, F}$, which is the best formula known by which to obtain the practical efficiency of the furnace. In this, of the constants, which have been determined empirically, $A = \cdot 3$ for an ordinary convection and forced draught; $B$ is a fractional multiplier to allow for miscellaneous losses, and which, with the best convection and forced draught, is unity; but for ordinary convection is $\frac{19}{20}$, 5 per cent. being deducted for these losses; and $F$ and $S$ may be taken per square foot of grate area.

The maximum rate of combustion in locomotives is about 125[1] lbs. of coal per square foot of grate per hour, $= F$. When the maximum or total amount of heating surface is used, $S = \frac{1025}{14 \cdot 84} = 69 \cdot 2$. The ratio, $\frac{S}{F} = \frac{69 \cdot 2}{125} = \cdot 55$, and the corresponding efficiency, $\cdot 59$.

The corresponding evaporative power from 212°, in which case the total theoretic evaporation $E$, has been found to be 13·82 lbs., is $E' = E \times e = 13 \cdot 82 \times \cdot 59 = 8 \cdot 15$ lbs. of water. From 62° Fahr., and at atmospheric pressure the evaporative power is

$$11 \cdot 97 \times \cdot 59 = 7 \cdot 06 \text{ lbs. of water.}$$

Another way of calculating the efficiency of the furnace is from the initial and final temperatures of the products of combustion, $\frac{T_1 - T}{T_1} = \frac{3044 - 600}{3044}$, which gives 80 per cent. for the efficiency, but this is a theoretic method, and the actual in nowise approaches it.

The more actual case, I think, would be to take the effective heating surface, 793 square feet, in which case,

---

[1] Forney.

$$e = \frac{E^1}{E} = 1 \frac{53{\cdot}6 \left(= \frac{793}{14{\cdot}84}\right)}{53{\cdot}6 + 37{\cdot}5} = {\cdot}586$$ for the actual efficiency, and if we deduct $\frac{1}{20}$ of this for the waste in unburned fuel, unburned gases and smoke, waste by radiation, conduction, etc., we have the ordinary efficiency of the locomotive furnace, ·557.

Taking the total heat of steam at 140 lbs. pressure at 1223·92 thermal units, and dividing the total heat of combustion of one pound of Cumberland coal, 13,363, by it, we find 10·92 lbs. of water to be the theoretic evaporative power, and the evaporative power that we should expect this boiler to exhibit, under the usual pressure of 140 lbs., would be $E^1 = 10{\cdot}92 \times {\cdot}557 = 6{\cdot}08$ lbs. of water per pound of coal.

*Boiler Power*, or its steam generating capacity, depends upon the grate area, the extent of heating surface, the draught, conducting power, and the quality of the fuel. Its available power also depends upon the application of the steam after it leaves the boiler. The horse power depends upon the amount of water it can convert into steam in a certain time, and this, in turn, is directly proportional to the amount of coal that can be burned on the grate. The maximum amount that this boiler can be expected to burn per hour is therefore $125 \times 14{\cdot}84 = 1855$ lbs.

Now in the $16 \times 24$ inches cylinder there are 4825·4976 cubic inches, or 2·792 cubic feet. If solid cylinders full of steam are used, these must each be filled and emptied twice in every revolution, or the amount of steam required will be $2{\cdot}792 \times 4 = 11{\cdot}168$ cubic feet. Suppose one of the conditions in the problem stated at the beginning of this part, to be a required speed of 25 miles per hour, which is about the average on the Eastern R. R. In one mile there are 5280 feet, corresponding to 88 feet per minute, so that the engine would have to move $88 \times 25$ miles $= 2{,}200$ feet per minute, and dividing by the circumference of the driving wheel, 16·36 feet, there would have to be about 135 revolutions per minute. Hence, $11{\cdot}168 \times 135 = 1507{\cdot}68$ cubic feet are used and must be supplied per minute.

The relative volume of steam, at 140 lbs. pressure, is 182·6. Therefore, $\frac{1507{\cdot}68}{182{\cdot}6} = 8{\cdot}26$ cubic feet of water to be evaporated per minute, which is equivalent to $8{\cdot}26 \times 62{\cdot}4$ (mean weight of a cubic foot of water) $= 515$ lbs., or 30,900 lbs. per hour.

As we have found, one pound of coal will evaporate 6·08 lbs of water under these conditions, and therefore $\frac{30,900}{6·08} = 5082$ lbs. of coal would be burned per hour. Now it will be seen by the tables in Part II, that with the ordinary weight of train, the steam was usually cut off at 10 inches of the stroke. Therefore, if only $\frac{10}{24}$ of the steam is used, the amount of coal necessary to be burned would be less, or $\frac{10}{24}$ of 5082 = 2118 lbs., which we see is rather more than this boiler can consume under the conditions, its maximum rate being 1855 lbs. per hour.

III. With the *Feed Apparatus*, we leave the treatment of the boiler proper, and enter upon that of the numerous boiler attachments. These continue also through the two succeeding divisions. Mr. Forney, in mentioning the accidents liable to occur to locomotives, of which he enumerates nineteen of the more serious, estimates the order of their importance as, first, accidents occurring to the locomotive as a whole, such as collision, running into an open draw, escape of an engine without any one on it, and running off the track; second, accidents to the boiler, such as its explosion, bursting of a flue, or blowing out of a rivet; third, failure of the feed apparatus; and fourth, breaking of the mechanism, as the bursting of a cylinder or a cylinder head, breaking or bending a piston rod, connecting rod, crank pin, wheel, axle, or spring, so that the right working of the feed apparatus is of much more importance than even that of the mechanism, and, indeed, second only to that of the boiler itself.

The feed apparatus, for the supply of water to the boiler, consists of a single acting plunger pump, and the injector. Sometimes the injector is dispensed with, and then the rule seems to be that there should be two pumps, each of which is of sufficient capacity to supply the boiler. In practice the apparatus used for the steady feed, or main supply, whether it be pump or injector, is placed upon the engineer's or right side of the engine looking forward from the cab. From the specification we see that the pump occupies this side, and is that which is in constant use while running, while the injector is only used at stations, or in case the pump or its connections should fail. The general arrangement of the pump feed is shown on plate *A*, its details on plate *B*. It consists of a plunger, $1\frac{1}{8}$ inches in diameter, working in a brass cylinder, its motion being derived directly from the cross-head, a set of pipes, cocks, and three valves of similar construc-

tion, called, in reference to their position, the *suction*, *pressure*, and *check* valves.

On opening one of the cocks marked *A*, upon the tender, in plate *E*, the water flows along the horizontal pipe shown in the general view, and enters the vertical apparatus shown in Figs. 34 and 33, at *B*. The two rounded vessels at either end of this act as air chambers, and between them the plunger, Fig. 35, works back and forth in a horizontal direction. On the first stroke, the plunger enlarges the capacity of the pump and its connections by its own volume and tends to create a partial vacuum; hence the water flows in and upward through the lower vessel, enters the pipe *D*, Fig. 33, compresses the air in the annular portion *C*, and passes upwards through the suction valve at *E*. The three valves all open upward with an amount of lift from $\frac{3}{16}$ to $\frac{1}{2}$[1] an inch, are placed in brass cages, which allow only the necessary amount of motion.

On the return stroke, or stroke number two, of the pump plunger, the suction valve closes, the water is forced through the pressure valve, *F*, by the mouth of the upper air chamber, *G*, along the curved pipe, *H*, shown in the general view, through the check valve, *I*, shown in plate *A*, and plate *B*, Figs. 29, 30, and 31, and into the boiler at a point just below the mean water level.

The manner in which the pump is put together is clearly shown in the drawings; in Fig. 34, the parts are held together by the bolts *K* and *L*, unscrewing which gives access to the suction and pressure valves, respectively.

The pump at every point has an elastic medium against which to act. The energy exhibited in the velocity of the moving column of water, on entering, is taken up by the compression of the air in *C*. On the return stroke, the direct pressure is equalized by the upper air chamber, and at the check valve it has the elastic cushion of the steam in the boiler. Without the useful recoil of the springs which these constitute, we can hardly estimate the shock, or water hammer, which would be produced at each reversion of direction of the pump plunger, taking place, as it does, *six times a second*, at ordinary speeds, and sometimes *ten* or *twelve* times.

The supply of water fed to the boiler is regulated by a feed cock in the suction pipe. To ascertain whether the pump is working or not, there is a small but very useful appliance, which was invented

[1] Forney.

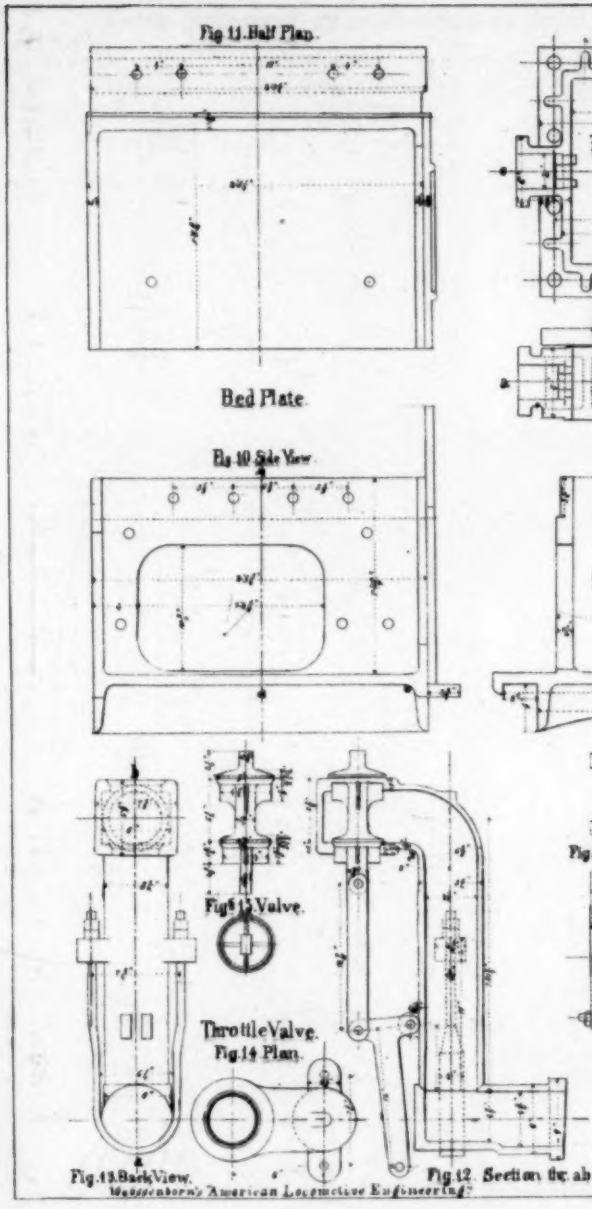
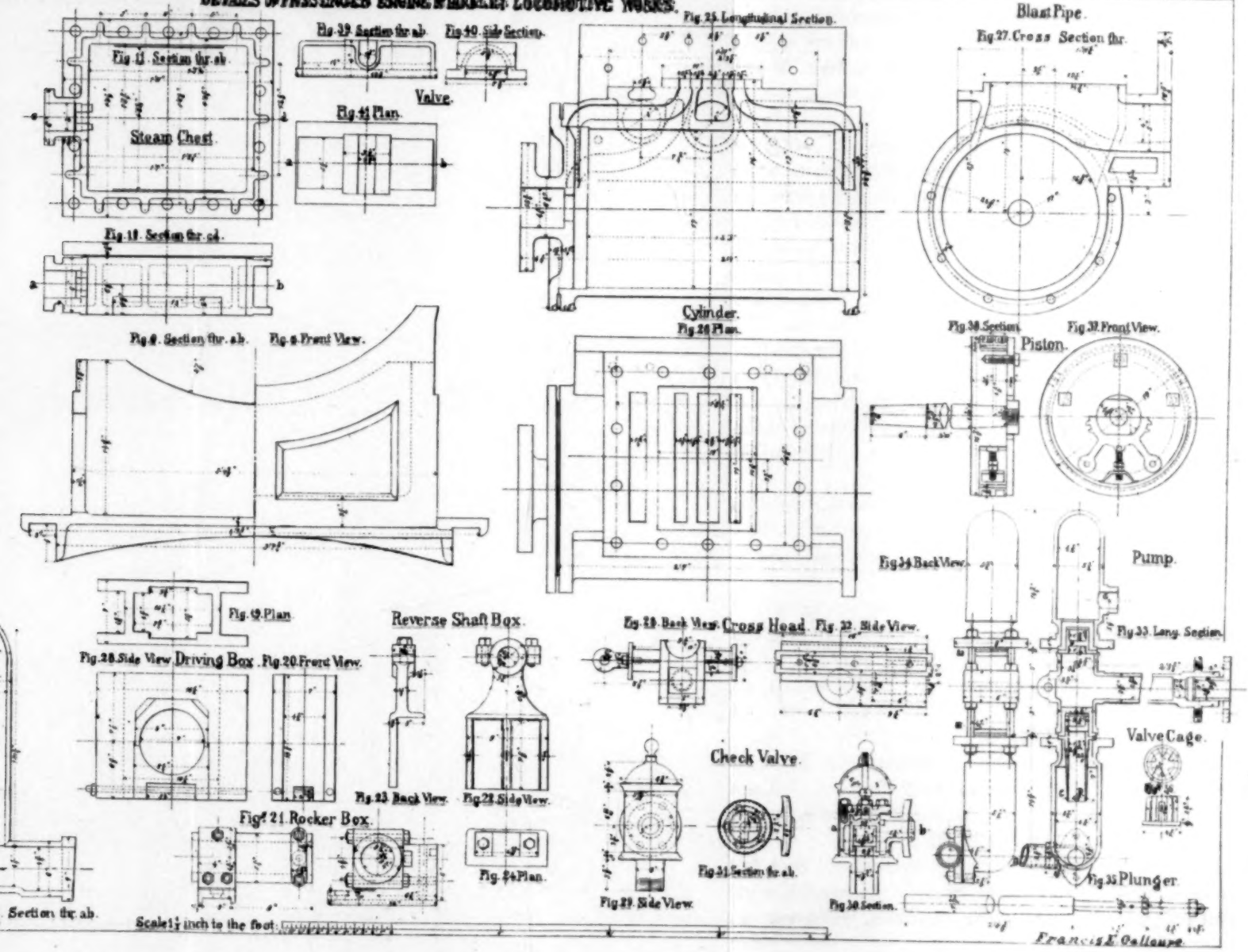


Plate B.

# DETAILS OF PASSENGER ENGINE AT HINKLEY LOCOMOTIVE WORKS.




Francis E. Galloupe.

by George Stephenson, called a "Pet Cock," and which is placed in the lower part of the upper air chamber. This little affair, when opened, lets out suddenly a stream of water, on the inward stroke of the plunger, as its position would indicate, which shows, when weak, that the pump is imperfectly working. It further shows which valve it is that leaks, or has become obstructed, and when the pump is in perfect order, it is sharp and well defined. In cold weather the pump and connections are prevented from freezing, by pipes conducting steam from the boiler to the suction pipe, by means of which the water is heated.

If a locomotive, supplied only with pumps, should be snowed up, which sometimes occurs on the New England roads, it would be necessary to lift the engine from the rails so that the driving wheels could rotate, when the pump could be worked and the boiler supplied with water; but all this inconvenience and labor will be obviated if the boiler be fitted with that delicate instrument, whose principle will be next explained, called

*The Injector.* Of this instrument there are several different forms,—the Sellers', Mack's, Rue's, and Friedmann's patents, besides the original Giffard injector, which was first patented by Mr. H. J. Giffard, in England, July 23d, 1858. In their construction they are of four classes, the lifting, non-lifting, self-regulating, and fixed. The original Giffard injector has been in use in this country about fourteen years, and with the improvements that have been made in it, is the form manufactured by Wm. Sellers.

The size, or capacity of an injector is determined by the steam pressure and quantity of water evaporated per hour, or the horse-power of the boiler. As far as their working is concerned, they may be placed in any position, upright, on their side, or inverted. The non-lifting injectors are used mostly for stationary boilers, and when placed upon locomotives, must be placed so low between the wheels, that the water will run by its own gravity from the tender and fill the instrument. In the lifting class, the water is drawn up through a suction pipe, as in the pump. In the fixed nozzle injector, the instrument works perfectly at but one pressure, that for which it is designed, and in the self-regulating, it works easily at a great range in variation of pressure, but from the more delicate and complicated apparatus thus necessary, the fixed nozzle is often employed.

(To be continued.)

## PRACTICAL TUNNELING.

[From the *Mining Journal*, Nov. 11, 1876.]

From the constant necessity for systematic tunneling operations in connection with the development of mining works upon the extensive scale usual in modern times, such works as Simms' Practical Tunneling[1] are almost invaluable. Mr. Clark remarks that as a monograph on tunneling Mr. Simms' work stands unrivaled, and it is as useful now as it was on the day it was first published. At the same time, since those tunnels were completed a great deal of valuable experience has been accumulated in tunneling, for many other tunnels have been constructed under different circumstances, and through ground of various geological formations. Other types of construction have been developed, of which it is scarcely necessary to state that the tunnel under the Col de Fréjus, commonly known as the Mont Cenis Tunnel, above 7½ miles in length, is the greatest and most wonderful achievement of the time. The engineering construction of the Metropolitan Railway, popularly known as the Underground Railway, in London, is a unique performance, which most men pronounced impossible before the event, and this great work is only less admirable than the Mont Cenis Tunnel. In the portion of the work added since the previous edition was issued the system of driving tunnels known on the Continent as the English and the Belgian systems—based on the bottom heading and the top heading respectively—are carefully investigated. Then follows a discussion of the ordinary casualties in tunneling, and is followed by details of the experience gained in tunneling in clay, marl, etc., in coal formations and in hard rock. The St. Gothard Tunnel, now in course of construction, which will when completed have a length of 9¼ miles, has been very fully described, the materials being for the most part drawn from the excellently prepared quarterly reports of the engineer.

---

[1] A Review of a Book on "Practical Tunneling; Explaining in Detail the Setting Out of the Works, etc. By Frederick Walter Simms, C. E. Third edition, revised and extended with additional chapters, illustrating the recent practice of tunneling as exemplified by St. Gothard, Mont Cenis, and other modern works. By D. Kinnear Clark, M. Inst. C. E. London: Crosby Lockwood & Co., Stationers' Hall Court, Ludgate Hill."

From the introductory chapter it appears that the tunnel on the Languedoc Canal, commenced in 1666, was one of the earliest instances of this description of work. The Hartshill Tunnel, on the Chesterfield Canal, 3,000 yards long, and the Sapperton Tunnel, on the Thames and Severn navigation, 2½ miles long, and lined with masonry, are amongst the earliest constructions in England. The method of proceeding with tunneling depends upon the kind of material to be excavated. The nature of the material is in ordinary circumstances ascertained approximately by means of boring and trial shafts, which are sunk from the surface over the axial line of the tunnel to be constructed through the intervening strata to the level of the lower part of the tunnel. Particular attention is required to be given to the practical geology of the material, whether rock, earth, chalk, or sand, and the skill of the engineer and the contractor is tested by the application of their knowledge of the subject to the development of safe and proper forms and proportions, as well as to the execution of the necessary works of construction. All unstratified rocks which are homogeneous and free from faults may be excavated, so as to leave the sides of the excavation vertical or nearly so, and thus a tunnel may be formed by merely driving a heading through the rock without the protection of an arch of masonry. It is generally only in such strata as clay-slate, granite, or other primary rock, that works can be left without artificial protection. In gneissous formations the walls of excavations may stand and endure unprotected, whilst it may be judicious and even necessary to line the arch. Mica schist, on the contrary, and particularly when loosened by distortion, most commonly requires to be substantially lined above the floor with masonry. But many stones whose strength and texture would, if they remained unaltered by exposure, enable them to stand forever, are affected by atmospheric air and moisture, and very speedily so by frost. Decomposed granite, called by miners potgrowan, is extremely troublesome in mining; it consists principally of feldspar and potash, as does the china-clay or kaolin of the potteries. The substance appears to have been formed by the decomposing action of the air, or of chemically formed oxygen. Pyrites has a natural tendency to decomposition when exposed to the air, and it affects everything with which it comes in contact. Chalk is a material which, in those parts where it first crops out—that is, at the top of the stratum—has

frequently given much trouble by reason of its inequality, and the common occurrence of potholes of loose gravel which, when unduly charged with water, break away the surrounding chalk. The presence of chalk veins in the mica schist formations of the St. Gothard mountain have been found to expose the rock to decomposition when opened to the air by the excavation of the tunnel. The diluvial strata are from their nature the least compact, and therefore require the most careful treatment. The alteration, too, in their position, which at some remote period of time has uplifted and distorted the original horizontal strata, renders them liable to further change of form by facilitating the operation of water—the element to which they owe their formation originally, and to whose continued action they seem peculiarly susceptible. Of these formations the most solid are gravel and sand. The other soils of this class are extremely variable. Some clays are firm and tenacious, others of a marly character are slippery; while quicksands and peat are proverbially treacherous. Clays, too, may be intersected by porous veins, which acts as conduits for water. The London clay has a notorious reputation with well-sinkers; even in the absence of moisture, if the clay be left exposed to the air for a few hours it expands and bulges inward. A well at Richmond of 4 ft. diameter was completely closed in one night by the swelling up of the bottom, although there was not any water in it. In mining operations the expansion of clay is well understood. The floors of old mines are always expected to swell upwards. The action of the air upon shale is well known; shale, though so tough and hard underground as to require the agency of gunpowder for its excavation, swells when uncovered, and becomes after a few weeks' exposure to damp and atmospheric action thoroughly decomposed, and falls to powder.

In the main portion of the book the geological features of the South-Eastern Railway are described, and a general account is given of the Blechingley and Saltwood tunnels, the observations made by geologists during the construction of the line having permitted of a very accurate and complete statement being made. In the second chapter is a description of the transit instrument, and the method of fixing and adjusting it is explained, the mode of using the instrument and securing accuracy being described with equal care. Having described the method of keeping the works straight in a horizontal direction, he explains how to make it correct in a vertical

direction or preserve the proper level. The fourth chapter explains the methods of shaft sinking in connection with tunneling operations—the trial shafts being chiefly considered—whilst in the succeeding chapter the mode of excavating and constructing the working shafts and supporting the brickwork by shaft sills and hanging rods. There is an interesting chapter on driving the headings, and some valuable estimates of cost. It appears that by horse labor it costs 2·85d. per ton to lift water and stuff an average of 104 ft. There is a chapter on excavation and timbering, and others on putting in the brickwork and finishing the tunnel with the junction lengths. In the portion of the work contributed by Mr. D. K. Clark, the relative advantages under varying circumstances of the English and the Belgian systems—the bottom heading and the top heading—is discussed, and he remarks that the greatest disadvantage of the system of bottom headings and break-ups in certain grounds consists in the lengthened exposure of the surface of the excavation to the action of the air, which in clays, marls and shales loosens the ground, and in rock opens the fissures. A chapter is devoted to casualties in tunneling, which will prove of great practical utility in suggesting some of the obstacles likely to be encountered. The chapter on the enlargement of railway tunnels is of considerable interest, as showing the peculiar difficulties arising from the disturbance of soils which had already been disturbed, and more or less displaced before. In the chapters on tunneling in hard rock, reference is made to the tunnels on the aqueduct of the Glasgow Water Works, to the Clifton Tunnel, to the Mont Cenis, and to the St. Gothard, and with regard to the latter work very complete details are given both as to the compressors, drills, etc., used, and as to the results obtained.

The work altogether gives evidence of the editor having devoted a large amount of labor to the revision and extension of the original treatise, and as the details are given with much minuteness, especially with regard to the most recent and approved practice—those details being made remarkably clear by the numerous illustrations accompanying them, the engineer who takes the book for his guide need have little fear of falling into error, or of being unable to cope with the many obstacles he is sure to meet with in carrying out his work. It is a really valuable volume for reference.

## TALL CHIMNEYS AND ELECTRIC CONDUCTORS.

From *Iron*, London, October 28, 1876.

There are few chimneys which have any peculiar historic interest, but an exception is presented in one built at Glasgow by Mr. Joseph Townsend, and attached to that gentleman's chemical works. This chimney is to its neighbors what Mount Blanc is to the rest of the Alps—a giant among pigmies. The foundation of this chimney was laid in March, 1857, and on the 6th of October, 1859, the coping was added at the top, at a height of 468 feet from the foundation, and 454 feet from the level of the ground.

At the foundation the outside diameter is 50 feet, and at the surface it has diminished to 32 feet, while at the top of the coping the diameter is 12 feet 8 inches. On the 9th of September, 1859, and while the chimney was still unfinished, and therefore before the mortar was dry, a storm occurred and resulted in swinging the chimney out of the perpendicular to the extent of 5 feet at the top. This accident, though perhaps directly due to the storm, had its origin in a neglect in the building process. Proper allowance had not been made for the contraction of the mortar used in setting the bricks, and as a consequence a certain number of planks were under a great pressure, being arched in the centre. Suddenly one of these at one side gave way in the oscillation caused by the storm, and with the unequal pressure the chimney was then forced from the perpendicular to the extent above stated. That the accident occurred in this way Mr. Joseph Townsend ascertained by personal observation. For a time some fear was entertained that the whole chimney would come down, but on the 21st of the same month measures were taken to prevent this, and by the 1st of October, the whole was restored to the original upright form. This was effected by sawing the chimney on the side nearest to an imaginary straight line. The following figures give the intervals at which cuttings were made:—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 128 | feet from the top | | 8 | 13 | feet below | 7 |
| 2 | 49 | feet below | 1 | 9 | 20 | " | 8 |
| 3 | 22 | " | 2 | 10 | 30 | " | 9 |
| 4 | 15 | " | 3 | 11 | 40 | " | 10 |
| 5 | 12 | " | 4 | 12 | 40 | " | 11 |
| 6 | 19 | " | 5 | 13 | 41 | " | 12 |
| 7 | 20 | " | 6 | | | | |
| | | | | | 440 | feet. | |

When the chimney was only two years old, it was struck by lightning, and a fire ensued, the composition gas-tubing being melted at a distance of 100 feet from the gas meter, though this latter was situated 20 feet from the chimney. To understand how this happened, it is necessary to state a few additional facts. The chimney was provided with an electric conductor on one side, and a coil, which united with the conductor near the ground, where together they were bound to an iron rod and passed through a well of water, situated near the side of the foundation, 7 feet square and 2 feet deep, and thence down about 8 feet into the earth. Now, into this well comes the drainage of the works, and, further, the discharge pipe from a water closet, and it was found, on investigation, that although the pipe actually discharging into the well was of stoneware, yet, further back, it was in connection with one of cast iron. This latter pipe being midway between the conductor and the gas composition tubing, must have served as a vehicle for the electricity, which must then have completed its circuit by the gas pipe, which was thereby melted, and, the gas escaping, caused the fire.

To prevent a recurrence of such an accident, the cast iron pipe was removed and one of stoneware substituted. All now went well till three years ago, when the chimney was again struck by lightning at 150 feet from the top, 30 bricks being then dashed out. Again an examination was instituted and it was found that a separation had been effected between the conductor and the rod of iron with which it was bound where it passed through the well at the bottom. This separation had probably happened before the accident occurred and so possibly caused it. A new rod 10 feet long and passing 8 feet into the earth, was now substituted for binding the conductor and coil together, and the whole was well tallowed to prevent oxidation, and was finally enclosed in a wooden box, of which the side of the chimney made the fourth. But a year ago the chimney was once more struck by lightning on the opposite side to that which was last attacked, that is on the side along which descends the conducting rod. On this occasion a part of the coping stone was knocked off, and Mr. Joseph Townsend, impressed with the necessity of making some material change in the whole system of protection from lightning, is now providing the chimney with an apparatus which, it is to be desired, will fulfil its object.

This arrangement may be described in a few words. On the top of the coping stone are fixed four equidistant rods about 3 inches wide and 1 inch thick; these terminate in stars or arrow heads, and above them in the centre ascends a rod 20 feet long, and higher than the rest, terminating in a double arrow head. All these are properly connected with bands of iron, and are placed in good connection with the electric conductor and coils.

As may be readily imagined, there is some difficulty and not a little danger in raising such masses of iron to the height of 470 feet, but still more difficult and dangerous is it to construct the apparatus at the top, and fix it and bolt it together, as is required. For besides the exposure of the workman to the gases from the chimney, the atmosphere is often highly electric at that height, and freedom from sudden wind cannot be ensured. The construction is nevertheless approaching completion, and the whole of it has been done by one man, Mr. R. Hall. He is, perhaps, the only man who would undertake such work, and yet he does it with scarcely a sense of danger, and certainly with none of fear. It seems as easy to him to walk about and work on the coping stone as it is to many of us to walk about on the ground.

In concluding this sketch, which we hope may prove of some interest to manufacturers who have tall chimneys attached to their works, we would merely point out that not a little success of the working of an electric conductor depends upon the way in which it is sought to distribute the electric current over the earth. It is not sufficient simply to pass the rod down so many feet into the ground, but it should terminate preferably in a plate or sheet of iron so as to present a good surface for diffusion.

---

**French Railway System.**—Great as is the mileage of some American railways, they are all surpassed by the greatest French railway system, the Paris, Lyons, and Mediterranean. At the close of 1875 the line in operation comprised 3195 miles, and the company is constructing, or has obtained concessions for, 1228¼ miles more, which, when completed, will make the system embrace 4423¾ miles. The directors are also considering other schemes of extension.

**Iron Making by Direct Process.**—According to the Plattsburgh (Lake Champlain) *Commercial*, a renewed attempt to make iron directly from the ore has been recently made. Although the description does not present any manifest novelty of method any way materially differing from the processes essayed over thirty years ago in New Jersey, and elsewhere in the United States, yet the allegation of success warrants a notice, with the trust that some minor improvements of manipulation may have surmounted the former difficulties and caused the wished-for result. The Catalan forge fires, for production of loupes of charcoal iron, have held their place in the Lake Champlain country, despite all improvements or extensions of blast furnaces, and "Northern blooms" still supply the material of charcoal boiler plate and tube skelps. It is in connection with these forges that reducing chimneys are now applied.

"Adjoining two ordinary forge fires, at the rear, is a brick structure 18 feet high, 11 feet deep, and the width of both fires, including the space between them. The interior space of this brick structure is occupied by 12 air-tight retorts, each 11 feet long, 3 feet high, and 11 inches wide, and each holding a ton of ore. They are constructed of fire brick, tongued and grooved and laid in fire clay. These retorts are arranged in four tiers, three one above the other in each tier, and surrounded by a series of fire flues, also of fire brick, connected with the forge fire below and a single smoke stack above. The ore, as it comes from the separator, is mixed with an equal bulk of fine waste charcoal (*braze*) and piled upon the top of the retorts, then a slide is drawn, opening a row of holes in the top of the upper retort, and the ore and braze run in, filling it. Here it remains 12 hours, subjected to a dull red heat, very small crevices being left open to allow the escape of steam from moisture and gases. After 12 hours another slide is drawn covering a similar row of openings, connecting this with the second retort directly underneath, and the ore runs down into the next retort below, while the upper one is filled as before with fresh ore from above. In the second retort the ore remains 12 hours, subjected to a little higher temperature, when it is let down into the third one by means of another slide, which, like the other, fits tightly; here it remains 12 hours more at a bright red heat, when it is run into an oven underneath, which is tight, with the exception of an opening in front, before which a sheet of flame from the forge fire is constantly ascending in its passage to the flues

above. From this oven it is hauled out by the bloomer as he needs it, falling upon the forge fire, when it is readily reduced, forming a loop, which is then drawn as usual under the hammer. Thus the ore is subjected to a red heat for 36 hours in air-tight retorts, together with pure carbon, and it is claimed that this process results in the thorough deoxidizing of the ore, which is just the necessary preliminary chemical process desirable for making the best quality of iron at the least possible expense. It will be seen that no extra heat is required above that of the ordinary forge fire—in fact, not so much, for the ore, being already red hot when it falls upon the fire, must of course melt with less heat than if it went on cold as in the ordinary method.

"One advantage, which is no slight one, is that the consumption of coal is very materially lessened by the process, and this would abundantly pay for the extra outlay, even if the quality of the iron was not improved. The blast is reduced from 2½ to 1¾ pounds pressure to the inch, and even with this reduction considerably more iron is made in a given time from each fire; and the fact that the fine particles of charcoal come out unchanged, after being subjected to a red heat for 36 hours, is the best possible indication of the perfection which has been attained in the construction of the furnaces, retorts, etc."

The resulting product of this process is somewhat exuberantly described in the *Commercial* with "foreshadowings of a great revolution in the process of iron manufacture by the Catalan forge process," but it seems that "every loupe of this iron is thoroughly tested, and these are afterwards assorted in three qualities—numbers one, two and three—before leaving the forge." This characteristic of direct process iron is well recollected, and it is hard on the workmen to say that one *result* of the process is to weed out the "number three men." It is stated furthermore that a test of the iron has produced horse-shoe nails "fully equal, if not superior, to those made from the finest Norway iron," which is exactly the kind of test that *raw* iron will stand best. It is, however, stated that the rough loupes are not hammered, but are rolled at once (of course, reheated) into 1¼ inch billet bars, which again are rolled into small rivet rods, such as are used in making cold rivets. So satisfactory a test does really offer a promise of a better end than previous attempts.

The *Commercial* says "the process has been patented by Mr. Edgar Peckham, the main principle involved being the heating of the ore

in air-tight retorts at different temperatures in the presence of carbon," but it is not easy to see how a patent could be either claimed or granted on the process or the principle. It has been impossible for the writer of this notice to avoid an unfavorable comment, but it will still be gratifying if, after a year's experience with the process, a definitely favorable report can be given, and our pages shall be then open for the purpose of publishing it.

---

# Chemistry, Physics, Technology, etc.

## THE FLOW OF WATER THROUGH AN OPENING IN A PIERCED PLATE.

By Robert Briggs, C. E.

(Read before the American Philosophical Society, November 3d, 1876.)

The consideration of the subject of the *vena contracta*, or section of a vein of water emerging from an orifice under certain conditions, is made a portion of the proceedings of the Philosophical Society of Glasgow, and appears in their volume X, page 145 *et seq.* Four papers are published, the first of which is an extract from a letter of William Froude, Esq., C. E., F. R. S., to Sir William Thomson, dated Cheston Cross, Torquay, 20th December, 1875. Mr. Froude is quoted[1] * * * * * "One result I have tried came out well:—The discharge through an introverted cylinder [tube] with keen edge. Here, by theory, the section of the jet ought to be exactly half of the aperture. For the conservation of stream line energy obliges the velocity to be that due to the head, while the conservation of momentum requires that the pressure on the aperture (which is here the sole operative pressure setting in the ultimate direction of the velocity generated) is only sufficient to create as much momentum, say, per second as will be resident in the length delivered per second, of a column of discharge, of half

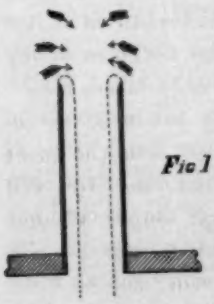


*Fig 1*

[1] The entire article is quoted; the hiatus indicated by asterisks exists in the published Proceedings of the Glasgow Society.

the sectional area of the aperture, if its velocity is that due to the head.

"The cylinder was quite smooth outside and the edge quite keen. The area ratio came out 0·503, 0·502, etc., instead of 0·500, and the little excess was obliterated; if the head was counted, to about one-fourth the diameter below the edge, as indeed it ought to be (I won't swear to the exact figure one-fourth), because till the motion of the particles is purely parallel to the axis, there must be some acceleration to be effected in the direction of the axis, and this demands the employment of some vertical pressure. * *

"In the *vena contracta* experiment with the thin plates and open air between the plates, the fluid was welcome, if it pleased, to start tangentially to the plane of the aperture as here indicated, and as it appears to do if closely studied. So also with the introverted cylinder; although it was not possible to see what happened I have no doubt that the motion of the particles *next* the edge was vertical upwards, the curvature being only such as the pressure in the contiguous stream would satisfy. If the experiment was not adroitly initiated, the water seized the inner surfaces of the cylinder and run out in an eddied condition, filling the discharge pipe. When, however, it was properly started, the contracted column below issued with beautiful smoothness and symmetry."

*Fig 2*

*Fig 3*

The second paper on the subject is an extract from a letter of Sir Isaac Newton to Professor Cotes, March 24th, 1710-11; from the "*Correspondence of Sir Isaac Newton and Professor Cotes, including Letters from other eminent men*," published in 1850, by Mr. J. Eddlestone, Fellow of Trinity College, Cambridge, from the originals in the Library of Trinity College. This letter possesses much value as showing Newton's experiment and discussions of the form of the *vena contracta*, and will be found interesting to examine in the proceedings of the Glasgow Society by those who have not ready access to the primary publication. Newton found the *vena contracta* from an aperture in the *side* of a vessel of thin sheet tin plate, five-eighths of an inch in diameter, to have, at the distance of one-half an inch from the hole, a diameter of $\frac{21}{40}$ of an inch; which was a reduction of diameter of $\frac{21}{25}$, and of areas of cross-section of 0·7058.

A foot-note to this letter of Newton by Mr. Eddlestone says, that "*Sectio vena contracta*" was a term used by Jurin, Philosoph. Trans., Sept.—Octo., 1722, p. 185; and that Dan. Bernouilli uses the same term, Hydrodynam., p. 65. Jurin also uses "*vena contracta*"; in all these cases the words denote the reduced section only, while subsequent usage generally applies them to the stream itself as a body, between the orifice and the point of reduced section.

The third paper is a discussion of the *vena contracta* by Professor James Thomson, LL. D., C. E., University of Glasgow, and is a mathematical discussion with six illustrations, intended to demonstrate under certain conditions, as for instance the supposed absence of fluid friction or viscosity, and a supposed great magnitude of vessel and depth of water compared with the dimensions of the orifice, that the jet of water issuing from an orifice in a thin plate, from a conical adjutage either protruding or re-entrant, has a section, where the stream flows out in sensibly parallel lines, of *more* than half the area of the orifice, and that this condition only ceases for a re-entrant nozzle, in the form of a parallel tube as treated of in Mr. Froude's paper. The conclusions of Professor Thomson do not seem to the writer as warranted by the conditions to which he limits his proposition. The value of the assumed force which he denotes by $P$ is by no means satisfactorily exhibited. As the purpose of this paper is to discuss other points, further notice of Professor Thomson's article may be omitted, only it will be assumed that the reader of this refers to the Glasgow Society's proceedings to see for himself what is set forth by the Professor.

The fourth paper is an abstract of remarks by R. D. Napier, Esq., who gave some consideration of this subject, which was published in 1866, in a pamphlet "*On the Velocity of Steam, etc.,*" in which he made the general assertion, with some qualifications, that the area of the true theoretical *vena contracta* is half that of the orifice. He says, "I have proved in the pamphlet referred to, that the pressure in the plane of the orifice is nearly half the pressure due to the head, and that from thence to the *vena contracta* [the words are here used in the sense of the section of least area] it gradually diminishes to zero. The diminishing pressure causes increasing velocity, and is thus the direct cause of the *vena contracta*. * * * "About three-eighths of the ultimate velocity and five-eighths of the *vis viva* are imparted to the water outside of the plane of the orifice, and it is absurd to attribute these effects either to what I

may call the converging momentum being transferred from one side of the orifice to the other, or to the converging particles preventing the free egress of the stream through the orifice, which are the only views hitherto offered to explain the cause of the *vena contracta.*"

This question of the *vena contracta* is a very pretty one in physics, and deserves a more complete and general discussion than it receives in the pages of the Glasgow Society. It should be recognized however, that it does not admit of the simplicity of investigation, either mathematically or experimentally, which the papers of Mr. Froude and Professor Thomson assume. It is impossible to divest the consideration from the fluid friction against the contiguous sides, surfaces, or the edges of the aperture, nor from the fluid friction of the liquid within itself which constitutes *viscosity;* nor yet further, from the frictional resistance to discharge into another medium (the atmosphere in this case); while the absolute strength of water is brought into action in the emerging column to the extent of pressure of the atmosphere. Values for these various elements can be accepted, and the mathematical investigation proceeding from them, would enable a thorough solution of the problem, in place of the extremely partial one essayed in the proceedings of the Glasgow Philo. Soc. Even the effect of dimension of vessel or volume or water with relation to the aperture might be made a part of the investigation and appear in the result.

In such an attempt to find a general solution of the theorem it would at once become evident, that there are two normal forms for the *vena contracta*, viz.: That, when the stream emerges *downwards* from an opening through horizontal edges, and that, where it emerges *upwards* through an opening of the same character. The first of these gives a pencil, whose shape for its longitudinal section at its upper end, or origin, will be controlled by the nature of the aperture, and by the effect of the initial directions of the particles of the effluent liquid (the theoretical *vena contracta, under pressure, but devoid of gravity*); modified by the effect of gravity, which would give to any descending pencil of a fluid, the motion of whose particles shall be established in approximately parallel lines, a hyperboloid contour. The second of these will give a sheaf, whose shape at the point of efflux, will be determined by the same laws; while it would now be modified at this point, by the *load* of the emerging fountain, and at the same time the form of the stream above (in this case attaining on some plane an absolutely contracted section) would be that of a hyperboloid

sheaf, with both *external* and *internal* lines of definition. If it be supposed in this second instance that the plane of efflux (of the orifice) is slightly deviated from the horizontal, so that the emerging stream is made to take a line out of the perpendicular one, the sheaf form would be disturbed; and at some quite small angle of deviation, a trajectory curve would take its place.

The general course of the stream would then have a modified parabolic curvature—a trajectory curve, which has been frequently discussed—but the exact contour of the pencil is still an open question. It is certain that when passing the point of greatest elevation, it would have, from its retarded motion, its greatest cross-section, and that this cross-section would be a flat oval of peculiar form; and it is probable that beyond this section, on the descending stream, it would become nodal, for the same reasons that a stream emerging from any orifice except a circular one becomes nodal.[1] In short the complete solution of the problem not only admits and assumes values for all the physical conditions, but it will embrace all directions of efflux from 0° to 180°, where 0° may be taken as the perpendicular direction, either upwards or downwards.

It is possible, for the purpose of illustration, to give some consideration of the *vena contracta* upon hypotheses similar to those of Prof. Thomson, and if other conditions are assumed at the same time, an *appreciation* of the phenomenon can be had. In truth, the view it is proposed to offer may go further than a mere appreciation, and may be made the basis for support of the other fundamental controlling conditions, and indicate the true line of procedure for mathematical investigation. Let us suppose, with Professor Thomson, that the effect of fluid friction, or viscosity, is neglected; that the magnitude of the vessel and the depth of liquid, is so large in relation to the dimensions of the orifice, that no appreciable velocity is imparted to the mass of liquid by the discharge; that the jet is one issuing downwards (so as to have the cross-section under absolutely uniform pressure); that the orifice is a circular hole in a thin plate—the flat bottom plate of the vessel—and that the effect of gravity on the stream after emergence be neglected, as well as the atmospheric resistance and the acceleration due to the column of discharge, in the production of a vacuum upon the sectional area; and the following sketch (Fig. 4)

[1] See article by Weisbach, "Ausfluss," in the "Allgemeine Maschinen Encyclopädie."

gives a general ideal view of the *vena contracta* under these suppositions.

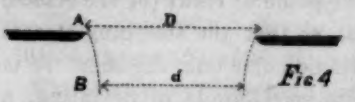


Fig 4

Weisbach[1] has observed that the actual diameter $= d$ of the vein of emergence from a thin plate, is about $0{\cdot}8\ D$; at the point $B$, which will be found from one-fourth to one-half the diameter ($= D$) from the plate; and this is accompanied with an efflux, as measured by the quantity of water discharged, of $= 0{\cdot}97\ v$, where $v =$ the velocity of flow $= \sqrt{2gh}$. Now it is an obvious conclusion that at any point on the surface of the *vena contracta* between $A$, the edges of the plate, and $B$, the point of minimum section, a particle of water must be in such equilibrium of pressure as to establish its direction of flow, or in other words its curved path; when it becomes apparent that some momentum must have been imparted to such a particle, to induce it to follow in its line of trajectory, instead of following the direction due to gravity, or to the application of the pressure normal to the head, or column of water above it. An attachment to the orifice can be constructed which will exhibit this phenomenon, or rather provide for its occurrence as a matter of necessity, as follows: Let there be an opening in a thin plate as before (Fig. 5), and let this opening be *guarded* or protected by a disc ($Z$) of the same diameter, $= D$, let this disc be placed so that its edges ($C\,C$) shall be one-eighth the diameter $= \frac{1}{8}\ D$ ($C\,A$) removed from the hole. On these suppositions, if the diameter of the section of least area, $= d$, be taken at $0{\cdot}707\ D$, then the area of the peripheral opening (at $C\,A$) will be equal to the area on the plane of ($B$). The line of effluent stream ($A\,B$) may be imagined to be a quadrant of a circle, which will then have, of course, a radius, $= 0{\cdot}147\ D$. Now let the face of

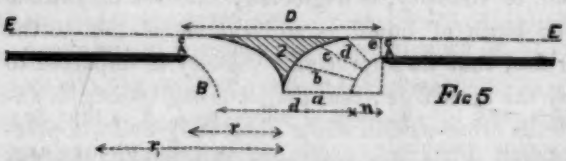


Fig 5

the disc $Z$ be made a conoid, so that the areas of the surfaces of the conical frustra $a\,b\,c\,d\,e$ shall be equal, or in other words, so that all the sections normal to the curve $A\,B$ shall be equal.

[The co-ordinates for this curve of the face of the conoid $Z$, in terms of $x$ and $y$, where $x$ is supposed to have its origin at point of the prolongation of the line $C\,A$ on the line $B$, are given by the equation:

[1] Weisbach's Mechanics.

$$y = \frac{\sqrt{[r^2 + n^2 \pm \sqrt{(r^2 + n^2)^2 - 4\,n^2\,x\,(2\,r - x)}] - 4\,(r - x)^2\,(r + x)^2}}{2\,(2\,r - x)}$$

In this equation $r =$ the radius of the opening commencing at the origin of $x$, and $n =$ the radius of the quadrant or corner commencing at the same point.

The assumption of the quadrant of a circle for the path of the effluent particle from $A$ to $B$, has been made in order to give a simple equation for, and ready comprehension of, the nature of the sections of the stream normal to its face on $A\,B$ where, by equalities of areas, uniform velocities would subsist; but the real curvature ($A\,B$) is obviously parabolic, and the plane of $B$ is infinitely distant from (below) the plane of $A$. Observation has shown, that at about one-fourth $D$ below the plane of $A$ the least section of *vena contracta* is apparently reached, and that below this plane of section, the pencil of descending current has its sides with only so much divergence from parallelism, as is due, almost entirely, to the acceleration of the falling stream. An elliptical quadrant which shall approximate to the true parabolic curve can be readily substituted by construction (or calculation) for the quadrant of a circle, in the equation above quoted, and the new values for $y$, will give loci for the curve of the face of the conoid $Z$ to correspond to the substitution. The value of the radius of the minor axis on the line $B$ as determined by observation, may be taken as that of ($n$) in the equation. By this method a very close approximation towards the true form may be attained.]

It will then result that the efflux from the peripheral opening $C\,A$ inwards, having any given velocity, will, in every part of the current, until the least section of the *vena contracta* on the plane $B$ is reached have a uniform and constant rate of speed; neither acceleration, nor transformation of head into velocity, will have occurred in the change of direction. If the consideration of the fluid friction, etc., be not taken into the question, and the velocity of efflux at $C\,A$ is that due to the head, that at $B$ is established and maintained; whence any liquid particle on the surface $A\,B$ must be in equilibrium of pressure, both from head or momentum in direction of its flow, *in which direction the entire head is transformed into velocity.* The plate, or plane surface of $D$, may be imagined to extend indefinitely in the directions, $E\,E$, in which case the velocity of flow of liquid, interposed between the plate $E$ and the bottom $A$, will decrease as the radial distances from the edge of the aperture; in inverse ratios of the radius $r$ to any

new radii $r_{,}$ $r_{,,}$ $r_{,,,}$: while the height, of liquid column corresponding to the several velocities, $= V$ at $r$, $V_{,}$ at $r_{,}$, will vary as $\left(\frac{r}{r}\right)^2 : \left(\frac{r}{r_{,}}\right)^2 : \left(\frac{r}{r_{,,}}\right)^2$ etc. The pressure or total height is supposed to have been completely transformed into velocity, $= V$, at the peripheral opening $C\,A$, and the stream or sheet of fluid would exert no transverse pressure at $C\,A$, either upwards or downwards; while the transverse fluid pressure on the supposed plate or the bottom of the vessel would vary as $\left(\frac{r}{r}\right)^2$ (at $C\,A$) to $\left[\left(\frac{r}{r}\right)^2 - \left(\frac{r}{r_n}\right)^2\right]$; $r_n$ being any assumed radial distance from the centre of the opening. Thus if the radius $r$ be taken as one-half inch, and that of $r_n$ as five inches (or ten times $r$), the velocity of flow towards the aperture at $r_{10}$ would be only one-tenth of that at $r$; the head required to produce the velocity at $r_{10}$ would only be one-one-hundredth of that corresponding to the velocity at $r$; and the pressure of the head remaining on the plate or bottom at $r_{10}$, would be ninety-nine–one-hundredths of the total head.

These two pressures on the plate and the bottom would be equal and opposite pressures, and if the plate were removed, the unbalanced pressure on the bottom would represent the force $P$, to which Professor Thomson gives an undefined value. Its total is, of course, the sum of the head upon the area of half the opening, and continuing the supposition of removal of the plate, it is encountered and balanced by the *momentum of the descending mass*, so that the bottom would now be in equilibrium of pressure, and the force $P$, as an unbalanced one, would disappear.

Returning to the examination of the proposition as shown in Fig. 5: the static resistance of the under surface of the conoid $Z$ in a vertical direction against the flow of water in its radial movement towards the centre of the orifice, and while following the path of the under surface of the conoid, is represented in total by the divergence at right angles of the entire effluent stream; $=$ to $\frac{1}{2}\,D$ of superfice, under the head which has produced the efflux. The reaction of the flow of liquid downwards is also equal to another statical resistance of the same value, and in the same direction; and as the total pressure on the conoid $Z$ from above, is its entire upper surface, under the head of liquid above it; the one pressure above balances the two pressures below, and the conoid itself is in equilibrium.

If it is now assumed that there exists no frictional adhesion of the liquid to the surfaces of the supposed plate, and of the bottom of the vessel, and the vessel is of indefinite extent, so that the velocity of entry at *E E* is reduced to an inappreciable rate of flow, then the condition of the formation of a perfect *vena contracta* will have been exhibited. The removal of the guide plate *E E*, and the removal of the bottom of the vessel, and substitution of a re-entrant tube, would replace the supposed frictionless surfaces by liquid mass, which if it is still continued to be supposed devoid of *viscosity*, would enter the peripheral surface *C A* with the same force, and in the same direction, and would still preserve the same perfect *vena contracta*. The removal of the conoid *Z* would provide a fluid conoid of the same shape, *or a distribution of internal strains* productive of the same resistance, and (still assuming the perfect liquid) the same perfect *vena contracta* would follow. If, however, there is admitted to exist a certain adhesion to the bottom of the vessel, or to the surface or edges *A A* so that the velocity of a particle on *A B* is less than that fully due to the head; the surface (*d*) would then become larger than $\frac{1}{2}$ *D*, the dimension *C A* would be properly increased to give the corresponding area of efflux, and the conoid *Z* would also have such a contour as would permit the uniformity of flow of each and every particle of the liquid at unchanged velocity, in any section of the *vena contracta* transverse to the direction of the flow. This increase of dimension of the cross-section *d*, and the effect of the descending pencil in accelerating the flow through it, can be taken as sufficient to account for Weisbach's observed value of $= 0{\cdot}8\ D$, and position of least section at $= \frac{1}{4}\ D$, as has been before quoted.

It must not be taken for granted that the writer is arguing that the conoid *Z* actually exists in the water, but it is here assumed for the purpose of showing that all the phenomena of the *vena contracta* are consistent with the supposition. Mr. Froude's "*tangential*" direction for the fluid in Fig. 2, which he says appears if closely studied, is a portion of the proposition, and this discussion exhibits "the imparting of velocity and *vis viva* outside of the plane of the orifice," as alluded to by Mr. Napier.

There is one other point worthy of notice in this radial flow of currents towards an orifice, and the radial direction at the edges of the opening. With or without the assumed central, neutral conoid, this flow is in exceedingly unstable equilibrium, especially when in contact

with a bottom plate (the friction or adhesion to which retards the flow), the radial direction may be diverted to a small extent, so that the particle of water where it curves at the point *A*, or at any other point on the line *CA* may possess absolute momentum out of the line towards the central axis of the pencil.

The radius of the openings calls for a very slight deviation of entering horizontal current, when its dimension is compared to the area from which this current is derived; and there is really but the slightest cause for the currents to direct themselves to the exact centre of the orifice. In point of fact the permanency of the *vena contracta* of downward discharge is derived in great degree from the pressure of the atmosphere, which is brought into action, by the descending pencil below it. The effect of a tangential afflux at the peripheral circle *CA* is to give a rotation to pencil, which at once accelerates, to some limit of discharge, and obliterates the *vena contracta*. The motion of the particles will yet remain limited *in any direction* by the head, but as the stream emerges with a rotary motion, the path of any particle becomes a spiral one, and the whole pencil advances, or is discharged, at a slower rate than is due to the particle velocity. In the case of the re-entrant tube, where the pencil is divested from the effect of gravity, by exhaustion of the air by the effluent stream passing from the tube, it is very difficult to get a *vena contracta*, as Mr. Froude testifies. This action of the tangential afflux is not confined to the emerging stream, but shows itself in the vessel as well, where a whirl is established which involves the entire mass of water enclosed. In the case where the bottom of the vessel has a funnel shape, this whirl sets up with great vehemence, and the centrifugal force of the established current may be sufficient, under favorable circumstances of form, head and dimension of vessel, to displace the entire central portion of the liquid, and the pencil of emergence will become a tube, whose core will be filled by an induced current of air. These phenomena of efflux are only noticed to embrace in my remarks some of the influences which effect the *vena contracta* where the conditions of formation are varied by adjutages, and to make it evident that neither the study of phenomenal nor the mathematical considerations involved, have been exhausted in the papers of the Glasgow Philosophical Society; while the present article does not pretend to do more than to indicate the direction in which inquiry should be pursued.

ON THE GROWTH OF THE

# ALKALI AND BLEACHING POWDER MANUFACTURE OF THE DISTRICT OF GLASGOW.

By JAS. MACTEAR.

Paper offered to the British Association for the advancement of sciences. Read before the Chemical Section, September 12th, 1876.

[Continued from Vol. ciii, page 63.]

## PART. IV.—ALKALI.

The production of alkali has been one of the Glasgow chemical industries since at least 1798.

It seems to have been made at first by furnacing kelp with charcoal and a little quicklime.

A method in use for the production of an impure alkali for soap boilers is described as follows in a note-book dated 1800 :—

"*To make the Hepar of Soda or Potass from the Sulphates.*"

"It is necessary to dry these salts in a reverberatory furnace, then "mix them with their weight of fir sawdust, and fuse them in a rever- "beratory furnace; when the surface becomes calm, the operation is "complete—let the sulphure run out. If it is a sulphure of potass, "break it up with a hammer, dissolve in water, evaporate it, and when "the salt begins to form, put in sawdust till it is thick.

"Then put it into the calcining furnace, roast it for an hour, two- "thirds of the sulphate will be decomposed, separate the undecom- "posed part by solution.

"If you operate on the sulphate of soda, after the first sulphure is "produced, add more sawdust, melt a second time to a sulphure, then "operate as with the potass."

The use of the still liquors from the chlorine manufacture early attracted attention.

These consisted chiefly of sulphates of soda and manganese, and were at first worked up into Glauber's salt, and the manganese seems to have been recovered to some slight extent.

In the year 1800 Lord Dundas had a work for the manufacture of mineral alkali in operation at Dalmuir.

The works were of considerable size for that period, as the following table will show, being a statement of the working for years 1801 to 1804 :—

VIEW OF MINERAL ALKALI WORKS.

| YRS. | ALKALI SOLD. | | | | PRICE PER TON. | BLACK ASHES SOLD. | | PRICE PER TON. | BARILLA SOLD. | | | | PRICE PER TON. | MURIATE OF POTASS SOLD | | PRICE PER TON. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. | C. | Q. | LB. | | T. | C. | | T. | C. | Q. | LB. | | T. | C. | |
| 1801 | 25 | 12 | 2 | 24 | £49·5 | 112 | 15 | £10· | 5 | 0 | 3 | 23 | £15· | 54 | 10 | £13· |
| 1802 | 62 | 11 | 0 | 21 | 47·9 | 31 | 5 | 12·2 | 14 | 6 | 0 | 0 | 20·2 | 122 | 0 | 13·24 |
| 1803 | 46 | 16 | 1 | 2 | 41·2 | ..... | | ..... | 23 | 17 | 1 | 25 | 20· | 121 | 10 | 13· |
| 1804 | 128 | 16 | 2 | 6 | 37· | ..... | | ..... | 21 | 6 | 3 | 0 | 20·9 | 90 | 0 | 6·5 |
| | 263 | 16 | 2 | 5 | 42· | 144 | 0 | 10·56 | 64 | 11 | 0 | 20 | 20·23 | 388 | 0 | 10·56 |

From the fact that soap lyes and the salts obtained from them were purchased in large quantity from the soap makers, it is probable that the process was substantially the same as that described as follows, in November, 1806 :—

"At Dalmuir they prepared from soap lyes got from Paisley and "elsewhere, 150 tons salts, and from these 120 tons crystals of soda "and 21 tons muriate of potass.

"The manufacture employed 15 workmen, and consumed 1200 tons "of coal at 10*s*. per ton, delivered at the works, and used 200 barrels "potass at 10*s*.

"Sal-e-nixon (sulphate of potass) and sulphur ashes (chiefly sul-"phate of potass), from nitre used in the vitriol manufacture.

"When potass is used, it is added to the mother liquors of the "first crystallization of soda, never put into the furnace with the soap "salts.

"When sal-e-nixon or sulphur ashes are used, the first is put into "the furnace with the salts, sawdust, and a little quicklime; the "second is first lixiviated.

"Their furnace yields 12 cwt. of flux per charge, and requires six "hours to flux it. They do two charges in 12 hours, but do not work "at night, it being found a preservation of the furnace to allow it to "cool during the night.

"The furnace is shut up when the charge is put in, and is never "stirred during the operation.

"Soda and muriate of potass are crystallized out alternately.

"The muriate of potass is never raked out of the hot solution of "the salts. The carbonate of soda is found to fall with the muriate "when the evaporation is continued until the salts begin to form.

"They do not know whether the decomposition of the muriate of "soda with the sulphate takes place in the furnace or in the subse- "quent process of evaporation.

"The mother liquors are heated with sawdust in order to make "them crystallize, that is, to carbonate them.

"The soda is seldom ever crystallized twice, particular attention "being paid to having the solution pure.

"The liquors are sometimes filtered.

"The soapers' lyes are evaporated in iron vessels, say circular ves- "sels of the usual form, in one piece, and yielding 8 cwt. salts per "day. They contain about 500 gallons each.

"The lead coolers are 9 ft. long by 4½ ft. broad, and 10 in. deep.

"The lead boilers are nearly of the same dimensions, but 15 in. "deep.

"They say they have found a substitute for potash in decomposing "the muriate of soda, which works equally well and does not cost "20*s.* per ton.

"The crystals are seldom ever free from muriate of potass, even "when the crystallization is pretty perfect in form.

"The muriate of potass, on the other hand, is seldom ever free "from alkali.

"When the potass is redundant in the liquors, they will not crys- "tallize.

"After the muriate of potass is crystallized, the mother liquor is "carbonated, and soda crystallized from it.

"*Charges on One ton of Soda.*

| | | | |
|---|---|---|---|
| "1·25 tons soap salts, at 6*l.*, 10*s.*, | £8 | 2 | 6 |
| "0·15 " potass, at 60*l.*, | 9 | 0 | 0 |
| "4·00 " coals, at 10*s.*, | 2 | 0 | 0 |
| "40 bags sawdust, at 4*d.*, | 0 | 13 | 4 |
| "Wages, | 5 | 0 | 0 |
| "Incidents, | 1 | 0 | 0 |
| "Tear and wear, | 3 | 0 | 0 |
| "Interest, | 2 | 10 | 0 |
| | "£31 | 5 | 10" |
| In all, | £31 | 5 | 10 |
| By 3 cwt. muriate of potass, at 13*s.*, | 1 | 19 | 0 |
| Net cost of 1 ton of crystals of soda, | £29 | 6 | 10 |

Selling price, about £60.

The yearly statement shows the make to have been 120 tons, and the cost 32*l.* per ton.

By another method in use about the same period, a mixture of 10 cwt. of soapers' salts, 6 cwt. of sawdust, and 3 cwt. of lime, was heated for 6 hours in a furnace until fluxed; it was then run off, and when cold, broken into small pieces and lixiviated in large vessels holding as much as 10 tons at a time, on a filter bottom of gravel and sand placed on coarse canvas. This filter lasted two to three months.

The liquor from this black ash deposited a considerable quantity of muriate of potass.

The remaining liquor was evaporated slowly without boiling till a pellicle formed, and then run off to crystallize.

To the mother liquors, from this crystallization, 3 cwt. or so of potash, in solution (according to quality of liquor), is added, the liquid again concentrated and crystallized, this being the third crop of muriate of potash crystals.

The mother liquor from this was called barilla liquor; it was boiled down to dryness, the salts mixed with their own weight of sawdust, and carefully roasted till the sawdust was consumed, never being allowed to flux.

Another method of carbonating was to make the salts red hot, and then mix them as quickly as possible with powdered charcoal.

This carbonated alkali was then lixiviated with cold water, evaporated till a pellicle formed, and after settling for about 12 hours, run into coolers to crystallize.

This soda was re-crystallized.

"In preparing barilla salts for bleachers" (this was actually what is now called soda ash), "the color may be regulated by the use of "nitre—if a white is desired, a greater quantity; if a blue, a lesser "will suffice.

"A note of the production of soda from kelp shows that from

"100·00 kelp,
"  2·72 charcoal,
"  7·29 potass (crude),
"200·00 coals,

"there should be obtained

"74·3 soda crystals,
"28·4 muriate of potass,
"33·0 sulphate of potass."

The methods which were adopted at the St. Rollox Works were very various as fresh light was thrown on the science of chemistry.

Almost immediately after the commencement of bleaching powder manufacture, the waste products of the stills were utilized for the production of alkali for soap making.

These residues, consisting chiefly of sulphate of soda and manganese, with varying quantities of common salt and sulphuric acid in the free state, were in the first case used in the manufacture of Glauber's salts; this was followed by a method of making sal ammoniac from urine collected in Glasgow in casks.[1]

This process was found unsuitable, probably from the difficulty of obtaining ammonia in sufficient quantity, and was soon displaced (in 1803) by a process, or rather a sequence of processes, which, with slight variations, continued in use for many years, until the introduction of the complete Leblanc system of alkali making.

This was the production of a crude alkali or black ash for use in soap making instead of kelp, then usually employed.

The earliest details which I have been able to find show that the still residuums were run into wooden tubs, where they were mixed with ground coal or sawdust till in a thick pasty state; this mass was then transferred to a reverberatory furnace and melted. When the decomposition had ceased, it was run out, and when cold, broken up and lixiviated with caustic lime, and the caustic lyes thus formed were used in the saponification of the fatty matters.

This was followed by the method of mixing the liquor obtained by lixiviating the above black ash with sawdust, and again furnacing, when a barilla was obtained worth at that time about 28*l.* per ton.

*Cost of One Ton Barilla from Residuum.*

| | | | |
|---|---|---|---|
| 6 cwt. salts, at 5*s.*, | £1 | 10 | 0 |
| 5 " lime, at 1*s.*, | 0 | 5 | 0 |
| 40 " coal, at 7*s.* 6*d.*, | 0 | 15 | 0 |
| Labor, | 0 | 6 | 0 |
| Tear and wear, | 0 | 2 | 0 |
| Yielding one ton barilla, costing | £2 | 18 | 0 |

And containing 3 to 10 per cent. alkali, worth then about 10*l.* per ton.

The soap lyes, after having become spent, were boiled down to salts, and barilla again made from them, much on the system already described as in use at Dalmuir.

[1] The obtaining of ammonia from urine has been tried at various times in Glasgow, and at present Mr. G. Chapman works a process which is believed to be very successful.

*Cost of One Ton Barilla from Soapers' Salts:*

| | | | |
|---|---|---|---|
| 14 cwt. of soapers' salts, at 5*s.*, . . . | £3 | 10 | 0 |
| 3 " lime, at 1*s.*, . . . . . | 0 | 3 | 0 |
| 20 " coal, at 7*s.* 6*d.*, . . . . | 0 | 7 | 6 |
| Labor, . . . . . | 0 | 4 | 0 |
| Tear and wear, . . . . . | 0 | 1 | 4 |
| | £4 | 5 | 10 |
| By 10 cwt. of muriate of potash, at 5*s.*, . . | 2 | 10 | 0 |
| One ton of barilla of 7 per cent. alkali, costing | £1 | 15 | 10 |

At first the muriate of potash was employed in the stills instead of common salt, but this was soon given up, and the muriate of potash was sold, chiefly to the alum makers of the district.

The manufacture of vitriol gave as a by-product a considerable quantity of "sulphur ash" residues, consisting of sulphate of potash, mixed with a little unburnt sulphur. This was used along with soapers' salts, and gave a larger yield of muriate of potash.

The mixture employed seems to have been at this time—

| | |
|---|---|
| 280 lbs. | soapers' salts. |
| 112 " | sulphur ashes. |
| 84 " | lime. |
| 112 " | coal. |
| 588 " | in all. |

Yielding 364 lbs. black ash, containing 10·5 per cent. alkali, and 25 per cent. insoluble.

In 1806 a trial was made of the mother liquors from the alum works as a source of potash; the black ash made from a mixture of this liquor and soapers' salts gave only about 6 per cent. alkali, and from this and other causes its use was soon abandoned.

"A statement of the products obtained at this time from 100 parts "of salt is subjoined:—

"100 parts salt,
" 83 " oil of vitriol,
" 56 " manganese,

"produce bleaching powder. The residue from above, with
"150 parts American potash of 81 per cent.,
"produces
"265 parts soda crystals.
"160 " sulphate of potash.
" 50 " of manganese recovered.

"It will therefore produce as much soap as 16 cwt. of kelp, even "reckoning kelp as containing above 3 per cent. of real soda, worth "10*s.* per cwt."

Methods more or less of this nature continued to be used until about 1816, when a good deal of correspondence with the French manufacturers, Chaptal & D'Arcet, took place, relative to the Leblanc system, which was finally adopted in 1818.

The following extract from the correspondence is of considerable interest, under date of July, 1816. Messrs. C. & D'A. say, in reference to their manufacture of soda:—

"They produced 44,000 lbs. per day of crude soda (black ash), "containing 20 to 21 per cent. alkali, which they sell at 20 francs per "quintal (equal to 16*s.* 8*d.*).

"It is produced from common salt obtained from the spontaneous "evaporation of the sea water at Marseilles, and costs about 9*d.* to "10*d.* per quintal. It is decomposed by sulphuric acid in the pro- "portion of 83 acid to 100 salt.

"In purifying their crude soda, and crystallizing, they always "experience a loss of 25 per cent. of the alkali, indicated by the acid "test in the crude soda."

These gentlemen utilized to some extent the muriatic acid evolved, by producing gelatine from bones, for the manufacture of soup, of which M. D'Arcet says he had made 1,300,000 portions of a quart each.

In 1818 these gentlemen had the intention to "establish works in "Liege and in London, for making soda, nitric acid, marine acid, "gelatine, etc."

In this year a process was at work at Port-Dundas for preparing a black ash for soap-making purposes, and this is the first record of the use of carbonate of lime (previously caustic lime seems to have been always used).

The mixture used was:—

| | | |
|---|---|---|
| 10 | parts | soapers' salts. |
| 2½ | " | poor kelp. |
| 2½ | " | chalk. |
| 5 | " | sawdust. |

This was fluxed for 6 hours, and gave a black ash testing 6 to 7 per cent. alkali.

In the end of this year, French soda was imported into London. It was in the form of black ash, and of three qualities.

No 1, containing 13 per cent. alkali, sold at £30 per ton.
" 2, " 12 " " " 26 "
" 3, " 11 " " " 25 "

It was manufactured at Marseilles by the Leblanc process, which had been fully established there for some years. Three qualities of soda were made for sale.

1. Crude soda (now called black ash).
2. Crystals obtained by the lixiviation of the crude soda.
3. Calcined residues from the "bitter water" (now called soda ash).

All these qualities had certainly been produced since the year 1807, works being in operation at Marseilles, Chauny, Rouen, Lille, Amiens, and elsewhere.

The first sale of soda made at St. Rollox on the Leblanc system, took place in the end of 1818. It was sold at 42*l.* per ton. Carbonate of soda, or soda ash, had been made for some months previously, but was apparently all consumed in the manufacture of soap.

The use of soapers' salts was still continued, and black ash was made for sale from the following mixture:—

1 cwt. Irish kelp.
1½ " soap salts.
1 " sulphur ashes.
1¼ " chalk.
1½ " coals.

In all, 6¼ cwt.

Yielding 3 cwt., 2 qrs., 14 lbs. black ash, containing 14 per cent. alkali.

In the following years soda crystals were sold in constantly increasing quantities.

*Table of Prices realized.*

| Year. | Price per Ton. | Year. | Price per Ton. |
|---|---|---|---|
| 1818, . . | £42 0 0 | 1844, . . | £6 0 0 |
| 1819, . . | 41 0 0 | 1849, . . | 5 10 0 |
| 1820, . . | 40 0 0 | 1854, . . | 4 10 0 |
| 1824, . . | 27 0 0 | 1859, . . | 6 0 0 |
| 1829, . . | 15 0 0 | 1864, . . | 4 15 0 |
| 1834, . . | 12 0 0 | 1869, . . | 4 5 0 |
| 1839, . . | 11 0 0 | 1874, . . | 5 10 0 |

The quantity made has rapidly increased from about 100 tons in 1818, to 1400 tons in 1829, and is now nearly 14,000 tons per annum.

Carbonate of potash was made in considerable quantities from about 1820.

It was produced from the sulphate of potash (obtained as a by-product in the manufacture of sulphuric acid) by the Leblanc system. The price in 1820 was 15*l.* per ton. On the introduction of nitrate of soda as a substitute for nitrate of potash, this manufacture was given up at St. Rollox; but it has revived again in the district within the last few years, considerable quantities being now manufactured, chiefly for their own use, by the bichromate and prussiate of potash manufacturers.

Soda ash, so-called, was first sold from these works in 1833, when it rapidly took the place of black ash, previously sold. In 1833 only 19 tons of soda ash were sold at a price of 22*l.* per ton; in 1865 the quantity had increased to 12,500 tons, sold at 9*l.* per ton.

The sulphate of soda required for the manufacture on the Leblanc system was at first prepared at these works in iron cylinders (such as are yet usually employed in the manufacture of nitric acid), and the muriatic acid evolved was condensed in upright earthenware condensers.

In 1822, pots of some form were introduced, the charge of salt weighing 4½ cwt., and yielding 560 lbs. muriatic acid of 40°.

Various improvements were introduced from time to time, amongst others, Gamble's improved furnace for salt-cake making; Gossage's condensing towers; the circulating system of vats for lixiviating black ash, first adopted at these works, and introduced by Mr. C. T. Dunlop.

The revolving black ash furnace of Elliott & Russell was tried at St. Rollox soon after its invention, but failed at that time to give satisfaction, the furnace at that time being too small and imperfect to compete with hand labor at the low rates then paid.

It was much improved by Messrs. Stevenson & Williamson, of the Jarrow Works, both in construction and in the method of working it, and became in their hands quite a success.

This form of furnace was again introduced at the St. Rollox Works, where there are now three furnaces.

These are worked on a system, patented by the writer, which has been eminently successful. It has increased the producing power of the furnaces over 50 per cent., with a large saving of raw material, and a corresponding diminution in the quantity of waste produced.

The amount of alkali usually lost in the waste being proportionately reduced.

This system is now employed in a number of the largest alkali works in England, and it is expected will shortly be at work in France.

The form of the furnace has at the same time been much improved; and while the first furnace erected at Jarrow was capable of working somewhere about eight tons sulphate of soda per 24 hours, the most recent of those erected at St. Rollox decomposes 50 tons in the same time.

The three revolving furnaces easily decompose 720 tons sulphate of soda per week of six days.

The most recent improvement introduced is a mechanical furnace for calcining or carbonating the soda ash. This has only been at work for a short time, but promises to be quite as successful as the black ash furnaces have been.

Other works in Glasgow and the district have been erected at various times for the manufacture of alkali, of which there are at present existing as alkali works, so far as I can ascertain, only four, viz.:—

Messrs. R. & J. Garroway, Glasgow.
" Orr & Brown, Irvine.
" W. Henderson & Co., Irvine.
" Arnott Bros. & Co., Kirkintilloch.

## Part V.—Caustic Soda.

The production of caustic soda was begun at the St. Rollox Works as far back as 1844, by means of a process introduced by a Mr. Weisenfeldt. It was made from the red liquors fused with nitre, and was perfectly white; but there being little or no demand for the article, the manufacture was for the time given up.

The manufacture was again resumed about fifteen months ago, and the various qualities and strengths of—

| | |
|---|---|
| Cream or unfused, . . . | 60 per cent. |
| White or fused, . . . | 60 " |
| Do., . . . | 70 to 72 " |
| White, double refined, . | 74 to 76 " |

are now manufactured.

## Part VI.—Manganese Recovery.

The recovery or regeneration of the manganese contained in the residuum from the bleaching powder manufacture was the object of constant investigation. Various methods were tried with but little success, amongst others, those of Binks and of Gossage.

The process still worked at St. Rollox is one invented by Mr. C. T. Dunlop in 1855, in which the acid still liquors are first neutralized with chalk, and the settled liquor is decomposed under pressure by milk of chalk; the carbonate of manganese thus obtained is washed, dried, and submitted to a heat of about 600° Fahr. for 48 hours, when it gives a black oxide of manganese of high strength.

A description of the process is given in most modern works on technical chemistry.

This method of recovering manganese is not in use at any other chemical works, the method now universally adopted being that invented by Mr. W. Weldon, which has been adopted by Messrs. C. Tennant & Co., at their works at Hebburn, near Newcastle-on-Tyne, in preference to extending the Dunlop process to that establishment.

Mr. Weldon's process is used, I understand, by all the other makers of bleaching powder in Scotland.

## Part VII.—Sulphur Recovery.

The position of the St. Rollox Works, and the enormous deposits of alkali waste which have accumulated during the long period of their existence as alkali works, caused the question of the recovery of the sulphur from the waste, or from the drainage liquor from the heaps, to become a very serious one. These drainage liquors at one time flowed into a stream called the Pinkston Burn, and from thence found their way into the Kelvin, and ultimately into the Clyde.

Many processes were devised and tried to keep down this flow of drainage, and a very large sum was spent in driving a series of galleries deep down in the rock under the waste heaps, to try, if possible, and intercept a number of springs of water which, rising under the heaps, dissolved and carried away the soluble sulphur compounds of the waste.

It was not till the beginning of 1868 that a process was at work in a way that might be called successful. It was one adapted by Mr. Ludwig Mond, and consisted in oxidizing the fresh exhausted waste while still in the vats by blowing air through, and then using the liquor draining from the heaps instead of water to dissolve out the sulphur compounds.

This process was worked for some years, but had two defects. There was a considerable amount of sulphuretted hydrogen given off in the process of oxidizing, and it was not found possible to utilize